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Perspectives on Science and Culture

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Perspectives on Science and Culture

Comparative Cultural Studies

Ari Ofengenden, Series Editor

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Edited by Kris Rutten, Stefaan Blancke, and Ronald Soetaert

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Introduction

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Kris Rutten, Stefaan Blancke, and Ronald Soetaert

This edited volume in the Comparative Cultural Studies Series explores the intersection between scientific understanding and cultural representation from an interdisciplinary perspective. The contributions in this volume analyze popular representations of science and scientific discourse from the perspectives of rhetorical criticism, comparative cultural studies, narratology, educational studies, discourse analysis, the cognitive sciences, and naturalized and evolutionary epistemology. As such, the volume fits within the theoretical and methodological framework of comparative cultural studies as a contextual approach to the study of culture from an interdisciplinary perspective. The main objective of this volume is to explore how particular cognitive predispositions and cultural representations both shape and distort the public debate about scientific controversies, the teaching and learning of science, and the development of science itself. Theoretically, this volume will integrate, on the one hand, C. P. Snow's concept of the two cultures (science versus the humanities) and Jerome Bruner's confrontation between narrative and logico-scientific modes of thinking and, on the other hand, cognitive and epistemological approaches to human cognition and culture, including science.

From this unique conciliatory framework, the volume explores how narratives and other cultural representations transform complex scientific issues into digestible bits of information based on particular selections and deflections. Some of the contributions analyze how scientific representations and metaphors of science take shape in pictures, cartoons, and television broadcasts, but also in novels and popular magazines. Others specifically focus on the implications of these representations and (mis)understandings for science education, both in formal and informal educational settings. Thematically, the contributions focus on a wide range of current debates about evolutionary theory, global warming, genetic modification, and so on. As such, it indirectly engages with discussions pertaining to the politics of science. The aim of this volume is to engage in the ongoing debate about the public understanding of science and is original in its interdisciplinary scope, ranging from philosophy, cognitive psychology, anthropology, and biology to literature, cultural studies, and rhetoric.

Public Understanding of Science

There has been increasing attention on the valorization of scientific research, in combination with a growing public debate about the uses and applications of scientific findings for social and economic purposes (Benneworth and Jongbloed). Media coverage of scientific findings plays an important role in shaping the public understanding of science and as such creates a context for socio-ethical debates about the application and development of scientific research (van Dijck). However, the communication of science is always, inevitably partial and this partiality raises issues of authority, creates potential misunderstandings, and complicates the public debate about science (Tietge). One of the main aims of science communication and programs aimed at increasing scientific literacy is to create a better public understanding of science and to emphasize its wider relevance to society (Gross, “Roles”).

Science communication often consists of a one-way flow from scientists to the general public by accommodating scientific findings to a nonexpert audience. Such a unilateral approach is indeed important for transferring relevant scientific knowledge to society but runs the risk of disregarding the contexts that give science its public significance and the ambiguities that arise from particular framings in the public debate (Gross, “Roles” and *Rhetoric*). Public concerns and opinions from stakeholders are often seen as (unwarranted) anxieties or vested interests rather than “assets” that have a role to play in the debate about scientific developments and applications (Bauer; Bauer, Shukla and Allum). There is an entangled and reciprocal relationship between science and society and therefore there is a need for a better understanding of the accommodation of scientific findings from experts to lay audiences, for an understanding of the different positions in the scientific and the public debate, and for an integration of scientific developments and the needs of society (Fahnestock; Gross, “Roles” and *Rhetoric*; Tietge, *Rational*).

For example, there is an ongoing body of research on the public understanding of genetics. Although there have been vast scientific advances in DNA technology, the socio-ethical and the legal and political debates still remain very contested and ambivalent. In her seminal work, *Imagenation,* José van Dijck has shown that the public imagination of genetics has undergone an important transformation during the decades that this branch of scientific research took shape, as the synopsis of her book notes: "From news stories of DNA strings escaping from our laboratories to the ongoing debates over bioethics, from James Watson and *The Double Helix* to the Human Genome Project, Van Dijck portrays the 'imaginary' tools of genetics as players in a theater of representation—a multi-layered contest in which special interest groups and professional organizations mobilize images in a heated debate over the meaning of genetics" (van Dijck). Popular representations of genetics do not necessarily reflect the advancement of genetic technology but these cultural accounts offer the repertoires and images with which different stakeholders debate the social, legal, political, and moral issues related to genetics research.

Rhetoric of Science

In this volume, rhetoric is introduced as one of the approaches to studying the public understanding of science. Rhetoric is the study and practice of persuasion. Scientists are inevitably engaged in the process of persuasion both within the academic community and outside, in public forums which need to be considered as different rhetorical situations (Simons; Harris; Journet). The focus of "new rhetoric" has expanded to many discursive domains, including science. There is a growing body of work on the rhetoric of science (Gross, "Roles" and *Rhetoric*; Gaonkar, "Idea"; Fahnestock; Harris; Simons), which focuses on the rhetoric of the scientific article (Gross et al.), the role of metaphors in the communication of science (Journet), the popularization of science (Tietge), and the critical assessment of emerging technologies (Zappen). As Alan Gross has argued, "The rhetorical view of science does not deny 'the brute facts of nature'; it merely affirms that these 'facts,' whatever they are, are not science itself . . . Whatever they are, the 'brute facts' themselves mean nothing; only statements have meaning, and of the truth of statements we must be persuaded. These processes, by which problems are chosen and results interpreted, are essentially rhetorical: only through persuasion are importance and meaning established" (Gross, *Rhetoric* 4).

The application of rhetorical studies to science has also been used to analyze the discourse of popular culture and how it relates to complex social phenomena such as the proliferation of pseudoscience (Gunn) or antipsychiatry (Rutten et al.). The rhetoric of science studies how scientists—as part of a discursive community—frame and communicate their knowledge, what they argue about and how, how scientists present their findings, and what genres, formats, and media they use to communicate those findings (Ornatowski). Despite the growing body of scholarship on the rhetoric of science, there is a need for further development of rhetoric as a framework for the public understanding of science, specifically given the increasingly mediatized public debate in an expert-dominated society (Fahnestock; van Dijck). A rhetorical approach to scientific discourse studies how particular framings of scientific findings and developments influence the socio-ethical debate, how this relates to science policy, and how an awareness of the rhetorical dimensions of science is important for scientific as well as nonscientific audiences and what the educational dimensions are of such a rhetorical awareness.

Two Cultures

In this volume, we also discuss the ongoing confrontation between science and the humanities by focusing on C. P. Snow's concept of the two cultures (and the so-called science wars) and Jerome Bruner's confrontation between narrative and logico-scientific modes of thinking. The concept of the "two cultures" refers to C. P. Snow's famous 1959 essay in which he problematized the gap between literary intellectuals and scientists. Until today, the concept has survived as a trope to frame the debate between the humanities and science. The notion of the two cultures was also central in the work of the educational psychologist Jerome Bruner, who confronted two modes of thought, two modes of cognitive functioning, each rendering different and distinctive ways of constructing reality and ordering experience: the *logico-scientific mode* and the *narrative mode*. For Bruner, these two modes are complementary though irreducible to each other and both have different operating principles, different criteria of well-formedness and different procedures for verification. The main difference is that logico-scientific arguments need to convince by applying procedures for establishing formal and empirical proof, and that narratives can convince of their lifelikeness by verisimilitude (Rutten; Rutten and Soetaert).

The logico-scientific mode of thinking focuses on general and empirically tested truths, and the knowledge that it produces should not be contradictory. The narrative mode, on the other hand, focuses on the intentionality of human actions (what and why?) and the context in which these actions took place (where and when?). From the narrative perspective, *truth* is approached as situated or contextual. Indeed, as Bruner states, “the imaginative application of the paradigmatic mode leads to good theory, tight analysis, logical proof and empirical discovery guided by reasoned hypothesis. . . . The imaginative application of the narrative mode leads instead to good stories, gripping drama, [and] believable (though not necessarily ‘true’) historical accounts” (13; also qtd. in Rutten and Stoetaert). It is not the aim in this volume to evaluate the difference between these two modes of thought. Indeed, Bruner himself has already pointed out the problematic aspect of this strict distinction between two modes of cognitive functioning (for an extended discussion of these two modes see Rutten; Rutten and Soetaert). However, based on Bruner’s theory of narrative as a specific mode of knowing, the aim is, among others, to study what can be learned from narratives and to explore how narratives can be used as tools to thematize and problematize the distinction between the two cultures.

Cognitive Science

Besides rhetorical and narrative approaches to the study of science and culture, this volume will also introduce perspectives from cognitive science. Cognitive science comprises several disciplines such as artificial intelligence, psychology, and philosophy that treat the mind as an information-processing organ. Decades of research have made it clear that the mind can only perform that function if it holds particular expectations about the world. If it did not, the mind would be absolutely clueless as to which information to attend to and how to handle it. An important category of such expectations is “intuitive ontologies,” which are spontaneous assumptions and inferences about the causal structure of particular domains of reality (Boyer). For example, folk physics deals with inanimate objects, folk biology is concerned with the living world, and folk psychology guides our inferences about agents. These intuitions work fast, automatically, and under the radar of conscious awareness, but they do exert an important influence on the beliefs we hold reflectively, both at the individual and at the cultural level.

The epidemiology of representations, developed by cognitive anthropologist Dan Sperber, explains how the susceptibilities of the human mind shape and constrain the formation and distribution of beliefs. *Ceteris paribus,* the representations that tap into our intuitive expectations stand a better chance of grabbing attention, being remembered, and transmitted. Played out over multiple transmissions, these representations will become the most popular within a particular population. In other words, they will become cultural. Intuitive ontologies, too, fix a lot of cultural content as they affect our beliefs about the world around us.

These beliefs might be intuitively appealing but they are usually not scientifically accurate. Creationist stories, for instance, tap into our folk biology and psychology, but hardly provide an adequate explanation for the origin and the diversity of species (Blancke and De Smedt).

For that reason, a proper understanding of human cognition in general and intuitive ontologies in particular is essential for the study, understanding, and improvement of science education, the public understanding of science, and even science itself. The minds of students and lay people are not blank slates that can simply be inscribed with any input. Instead, they come equipped with naive conceptions of the world, which constitute formidable cognitive obstacles for teachers and popularizers to overcome (Shtulman). Recently, much research in cognitive and developmental psychology, philosophy, and the history of science has been done on how intuitive ontologies make possible and thus influence the development, understanding, and acceptance of scientific theories and concepts (Carey and Spelke; Carruthers et al.; Evans et al.; Heintz; Nersessian). This volume aims to make a contribution to this literature and tease out the implications for the development, teaching, and understanding of science.

Naturalized, Social, and Evolutionary Epistemology

The philosophical tradition of naturalized epistemology takes seriously the insights from the cognitive sciences to understand the processes of knowledge generation and acquisition. As evolved biological creatures, humans have only limited cognitive and sensory abilities. In order to overcome these limitations and to develop and sustain counterintuitive scientific concepts, scientists rely on all sorts of help such as observational tools (e.g., telescopes), conceptual tools (e.g., analogies), and reasoning tools (e.g., logics). For that reason, philosopher Susan Haack describes science as common sense, but "more so" (101). One important scaffold is criticism by others. It is natural for us to look for arguments and facts that confirm rather than contradict our position. Hence, to have our views corrected, it is crucial that we submit them to the critical eye of our peers, who are similarly predisposed to defend their own ideas, but who are very happy to detect any errors in the beliefs and arguments of others (Mercier and Heintz). Science is thus necessarily and inherently social. To understand how science works, therefore, one needs to investigate how the social dimension adds to the development of scientific knowledge. This is the domain of social epistemology, to which rhetorical, historical, and sociological studies of science have made important contributions. These studies have clearly demonstrated that scientific insights do not result from rigidly applying the scientific method, but emerge from the interactions among fallible human beings. However, in contrast to popular postmodernist and relativist interpretations, the social character does not infringe upon, but rather results in and corroborates science's epistemic strength (Goldman; Haack; Longino).

Evolutionary epistemology is the strand of naturalized epistemology that focuses on the evolutionary dimensions of knowledge generation. This philosophical project comes in various shapes. Evolutionary epistemologists such as Donald Campbell, Karl Popper, and David Hull have argued that science proceeds in ways analogous to biological evolution. Various hypotheses provide the variation from which the ideas and beliefs that best fit the world are selected and retained. Recently, however, the focus has shifted to the study of the implications of evolutionary approaches to the human mind for our understanding of science. How do our evolved abilities and constraints affect the course of science? More broadly, the term "evolutionary" also refers to a populational view that aims at explaining the distribution and stability of particular beliefs and ideas within the scientific culture. An epidemiology of representations enables us to identify and map the various causal factors, including our evolved abilities and the specifics (e.g., institutions, social arrangements, artifacts) of the environment that the minds of scientists engage with. As such, an epidemiological approach opens the way towards the integration of the various studies of science, and consequently, of the humanities, social sciences, and biological sciences (Heintz).

Consilience

Because of its interdisciplinary scope, this volume underwrites the reconciliation of rhetorical, narrative, cognitive, and epistemological perspectives—although some of the contributing authors are still skeptical. Whereas the rhetoric of science investigates which communication tools and strategies scientists deploy to convince others, cognitive science helps to shed light on why scientists use these particular tools and strategies and not others and why some, but not others, are successful. More fundamentally, a cognitive approach also helps to explain why arguments play such an important role in science, science communication, and education: they are constitutive of human reasoning—that is, of providing (convincing) reasons to persuade someone else of one's views (Mercier and Sperber; Sperber and Mercier).

Cognitive science also makes a valuable contribution to the debates about the two cultures in the sense that it puts doubt on the existence of a sharp boundary between the two. Cognitive approaches to science assume that scientific thinking builds on ordinary cognition. Hence, there is no essential property, no silver bullet by which one could distinguish scientific from so-called other ways of reasoning. Scientists, too, rely on narrative thinking and other intuitive means of reasoning to develop their counterintuitive theories. This is not to deny that scientific cultures differ from other kind of cultures—science has its own institutions, organizations, procedures, and so on—but a cognitive approach implies that the difference will not be as clear-cut as the traditional two-culture approach suggests. An epistemological project that integrates the cognitive and cultural dimensions will enable us to develop a fine-grained understanding of the various scientific cultures, how they generate knowledge, and the similarities and differences between them. At the same time, it helps to explain what happens to scientific concepts outside these cultures, when transmitted to the larger public via (popular) science communication and education.

Contributions

In part 1, "Narrative and Rhetorical Perspectives," the volume brings together new work on the public understanding of science from the perspective of literature, narratology, cultural studies, anthropology, and rhetoric. In his chapter, "Experiencing Nature through Cable Television," David J. Tietge explores the relationship between cable television representations of nature and biology and how they influence the public understanding of environmental networks. The author argues that the metaphors, delivery, content, and orientation of such programming are guided by what Kenneth Burke calls an "occupational psychosis," a collective orientation that mirrors the economic principles of the culture in which such "edutainment" has been produced. More specifically, he is interested in how cable nature programming frames nature entertainment as a commercialized product that is to be consumed, capitalized on and expanded. According to Tietge, the anthropocentric nature programs discussed in his chapter start from the ideal that giving the audience what it wants—by relating to familiar ideological orientations such as *war, conflict,* and *competition*—is more profitable than representing nature from the traditional perspective of orthodox biological science. Representing nature as a product thus inevitably affects public attitudes about nature and the environment. In the final section, Tietge therefore argues that there is a need for a "rhetorical literacy" which would include "instruction on all educational levels in language structure; close critical readings of popular texts, including cable nature programs; how logical arguments are constructed; what can be done with existing knowledge and how new knowledge can be made; and how people, agencies, corporations, and other institutions all have rhetorical reasons for presenting knowledge in a preordained way."

In his contribution, "Steven Pinker and the Scientific Sublime: How a New Category of Experience Transformed Popular Science," Alan G. Gross argues that although the rhetoric of science has become a vital subfield within rhetorical studies—a field within which he has been working for a long time already—the rhetoric of popular science has been largely ignored. Alan Gross has recently been working on a book project entitled *The Scientific Sublime: How Popular Science Unravels the Mysteries of the Universe,* in which he explores the popularization of science by (contemporary) scientists and science writers such as such as Steven Weinberg, Richard Feynman, Stephen Hawking, Richard Dawkins, Stephen Jay Gould, Brian Green, Rachel Carson, and Lisa Randall. He focuses on their argumentative skills to persuade the general audience about how science can answer fundamental questions about the human being and the universe, amongst other topics. Gross argues that these authors employ an overarching rhetorical concept, the *sublime,* as a category of experience that generates a sense of wonder at the discoveries of science. In his contribution to this volume Gross starts from this larger project and develops a critical analysis of the work of Steven Pinker. The sublime, he claims in this chapter, is a persuasive resource that is being used by Pinker and other scientist-popularizers. The author argues that Pinker's major works share a single overriding assumption: "science can be relied on to shed significant light on subjects far removed from the laboratory or the observatory and can astonish us by its revelations about language, about the mind, about human behavior generally, and about violence in particular." Gross argues that the scientific sublime is invoked and evoked in each of these works.

Although this specific reading and analysis of the work of Pinker is of course open to debate and discussion (and the work of Pinker and the topics he explores in his popular books have been discussed from many different perspectives), it is an example of a critical assessment and analysis of the rhetoric of popular science and popular scientists. It also exemplifies the complexity of bringing scientific debates to a larger audience through popular science.

In his chapter, "Architectonic Discourses and their Extremisms," Barry Brummett starts from the question: "What can humans know with some measure of confident certainty, and what can we know that must always be largely contingent, exigent, and—in a word—arguable?" Taking Aristotle's distinction between discourses that offer sure and certain systems to guide distinctions, and those discourses (primarily rhetoric and dialectic) that manage decisions that are contingent and uncertain, Brummett explores a range of discourses that have historically claimed to be architectonic, or ruling, discourses. The author claims that the extremism consists not in resorting to sure and certain systems to guide decisions, but instead in resorting to these systems to guide decisions that ought to be decided rhetorically. The extremism in architectonic discourses is illustrated in a brief analysis of a website opposing childhood vaccinations. Brumett argues that the search for an architectonic discourse is a natural human desire. However, his contribution can be read as a plea to take any architectonic discourse with a great deal of caution.

In his chapter, "Science and the Idea of Culture," Richard van Oort argues that the conflict between the sciences and the humanities should not be understood in terms of the local "cultural" differences between scientists and humanists (C. P. Snow's "two cultures"), but rather in terms of the more fundamental problem of language origin: "Is language an extension of animal communication systems, or is it something radically different? Is it explainable in purely Darwinian terms, or is it an evolutionary anomaly (i.e., without precedent in evolutionary history)?" Van Oort argues that when it comes to explaining culture, science inevitably presses up against its limits. The central paradox of culture, according to van Oort, is that culture depends upon biology—"because culture requires brains and brains are the products of biological evolution"—but at the same time culture is also an institutional given. Van Oort starts by discussing the work of C. P. Snow, who criticized humanists for failing to take an interest in the work of their colleagues in the sciences and concurs that a genuine dialogue between humanists and scientists is rare. But van Oort argues that the problem of human origin (and specifically language origin) is one area in which dialogue seems both desirable and necessary, because it concerns both parties alike: "the sooner humanists recognize their stake in this fundamental question, the sooner they will be able to overcome their anxiety about the function of the humanities in a culture that privileges science as the only form of 'serious' cognition."

In their contribution, "A Rhetorical Analysis of the Two Cultures in Literary Fiction," Ronald Soetaert and Kris Rutten reconstruct the debate between and about the "two cultures" from a rhetorical perspective (focusing on "science wars" and perspectives from the "third culture"). Science and literature are described as particular terministic screens and the binary oppositions between these different "ways of seeing" are problematized. The major focus is on the importance of rhetoric and narrative in general and the role and function of the humanities—literary culture—in particular. The authors analyze two novels (*Saturday* and *The Children Act*) as a case study to reflect upon how the novelist Ian McEwan problematizes and thematizes the confrontation between art and science. They argue that McEwan participates in the debate about the two cultures with novels with essayistic ambitions on the one hand, but that he accommodates scientific facts and arguments into his prose on the other hand. The fact that these McEwan novels are vehicles that reflect upon the relation between art and science implies that he uses the novel as an allegory to discuss major social and cultural problems. The works of McEwan that are discussed in this chapter can be read as part of an ethical turn in literature and a revival of humanism in twenty-first century literature. Both novels reflect upon (and defend) traditional humanistic values in general and the function of literature in particular.

In his chapter, "The Missing Link and Human Origins: Understanding an Evolutionary Icon," Peter C. Kjærgaard argues that in the history of evolutionary theory no single topic has attracted so much attention and caused so much public debate as the question of human origins. In the discussions following the discovery of hominin fossils in the late nineteenth and early twentieth centuries the idea of the missing link between humans and animals turned into what has historically become one of the most powerful icons of evolution. Until the mid-twentieth century, however, both adherents and critics of evolution hailed the missing link as a crucial proof of the correctness of the theory of human evolution. It continued to be a hot topic in public debates and as such a good selling point for popular science books equally exploited by journalists, professional science writers, and scientists. Despite the fact that the idea of a missing link as a necessary piece of evidence for human evolution bears no meaning in contemporary science, it is wrong to think that is has no relevance. The missing link's lasting effects on public understanding of human evolution has made it far more than a mere cultural product and as such it continues to be a problem in public engagement. This chapter presents a brief history of the missing link as an evolutionary icon in popular and scientific contexts.

In part 2, "Cognitive Perspectives," the contributions focus on how findings and insights from within the cognitive sciences can help us to understand and improve the public understanding of science. In her chapter, "Suspicion toward Science and the Role of Automatic Intuitions about Origins," Elisa Järnefelt argues that skeptical public attitudes to evolutionary theory and climate change are anchored in the intuition that nature has been purposefully created by a supernatural being. As people will not easily revise their intuitive beliefs about these issues, scientists face the enormous challenge of finding ways to override them when communicating with the public. She concludes with a couple of suggestions in regards to science education and communication.

In her chapter, “Bridging the Gap: From Intuitive to Scientific Reasoning—The Case of Evolution,” Margaret Evans examines the use of intuitions to jump-start more sophisticated reasoning, as has been proposed for mathematics. The question addressed in this chapter is whether core intuitions can also jump-start biological reasoning. Intuitive ideas can offer an immediate action plan that allows us to make a rapid appraisal of the human mind or the natural world. Yet, there is a downside, such as a reliance on what may be inaccurate scientific judgments, based on cognitive predispositions such as anthropomorphic or essentialist reasoning. Studies conducted with museum visitors will be used to support the argument that specific cognitive predispositions can both help and hinder understanding. Margaret Evans argues that core intuitions can provide a series of stepping-stones, which, if navigated with care, may promote science learning.

The chapter by Andrew Shtulman, “Missing Links: How Cladograms Reify Common Evolutionary Misconceptions,” provides an excellent example of how thinking tools can enforce rather than override intuitive misconceptions. Developed as a conceptual tool to understand common ancestry and phylogenetic relationships, cladograms also tend to strengthen several popular misconceptions about evolution. This chapter focuses not on what the cladograms represent, but on what they fail to represent: extinction, diversity, and variation. These omissions are unproblematic in a scientific concept but they lead people to miscomprehend these three important evolutionary concepts.

In the final chapter of this section, “Representations of the Origin of Species in Secular (France) and Religious (Morocco) Contexts,” Dominique Guillo reveals the complexity of people’s ideas concerning evolution. In France, people who claim to accept evolutionary theory hold views that in fact come very close to intelligent design, which they share with nonevolutionists in Morocco. This shows the perpetual influence of cognitive biases. However, Guillo also finds that people’s representations of the origin of species are often blurry and cannot be compared to the well thought out beliefs of evolutionary biologists. Instead of treating the blurriness as noise that needs to be removed to get at people’s true beliefs, scientists might better regard it as characteristic of people’s representations of the origin of species.

In part 3, "Epistemological Perspectives," we consider the epistemological implications of the social and cognitive aspects of science. In his chapter, "Updating Evolutionary Epistemology," Christophe Heintz considers Donald Campbell's evolutionary epistemology and specifies why it is a worthwhile project for explaining the evolution of science as a specific case of cultural evolution. However, he also criticizes Campbell's evolutionary epistemology for assuming that blind variation and selective retention is the process through which science evolves. This assumption, the author argues, is at odds with much of what we know about scientific cognition and the history of science. Heintz therefore proposes an updated research program for evolutionary epistemology, which faces new challenges.

The following chapter, "Intuition in Science Education and the Public Understanding of Science," by Stefaan Blancke, Koen Tanghe, and Johan Braeckman, examines the role of intuition in science communication in general. They start from the double role intuition plays in science itself: as a cognitive bias it detracts scientists from finding out about the real world, but as a scaffold it is indispensible for the construction of highly counterintuitive scientific concepts and theories. This double role puts science communicators in a peculiar position. On the one hand they need to develop educational tools, practices, and strategies to avoid the pitfalls of our intuitive reasoning; on the other hand they need to appeal to the very same intuition to instill a scientific understanding in their audience. As a result, some approaches that seem promising at first may turn out to have the opposite effect.

In the final chapter, "Vindicating Science—By Bringing It Down," Maarten Boudry and Massimo Pigliucci argue that there is no stark difference between the social and the rational. Nor is it the case that true beliefs are self-evident and that only flawed beliefs require a causal explanation. Instead, if we want to explain science's epistemic superiority, we need to take into account the factors that allow for and sustain the development of scientific beliefs, including the social.

Part 4 contains a thematic bibliography on narrative, rhetorical, cognitive, and epistemological perspectives on science and culture.

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Part 1

Narrative and Rhetorical Perspectives

The application of rhetorical and narrative approaches to science have been used to analyze the discourse of popular culture and how it relates to complex social phenomena such as the proliferation of pseudoscience or antipsychiatry. The rhetoric of science studies how scientists—as part of a discursive community—frame and communicate their knowledge; what they argue about and how; how scientists present their findings; and what genres, formats, and media they use to communicate those findings. Despite the growing body of scholarship on the rhetoric of science, there is a need for further development of rhetoric as a framework for the public understanding of science, specifically given the increasingly mediatized public debate in an expert-dominated society. A rhetorical approach to scientific discourse studies how particular framings of scientific findings and developments influence the socio-ethical debate, how this relates to science policy, and how an awareness of the rhetorical dimensions of science is important for scientific as well as nonscientific audiences and what the educational dimensions are of such a rhetorical and narrative awareness.

In part 1, this volume brings together new work on the public understanding of science from the perspective of literature, narratology, cultural studies, anthropology, and rhetoric.

Chapter 1

Experiencing Nature through Cable Television

David J. Tietge

Abstract

This chapter discusses the relationship between cable television representations of nature and biology and the influence they wield over public understanding of environmental networks. The metaphors, delivery, content, and orientation of such programming are driven by what Kenneth Burke calls an "occupational psychosis," a collective orientation that mirrors the economic principles of the culture in which such "edutainment" has been produced. More specifically, the author is interested in how cable nature programming leaves us with nature entertainment as a product—a distinctly commercialized thing to be consumed, a franchise to be capitalized on and expanded. Just as Disney did before them, the anthropocentric nature programs discussed in this essay reflect an ideal that giving the audience what it wants—by tapping into the ideological orientations like war, conflict, and competition they already possess—is more profitable than representing nature from the stodgy seat of orthodox biological science. Moreover, the chapter addresses the outcomes of representing nature as a product and how this affects public attitudes about nature and the environment.

The nature documentary, as a genre, has a long mass media history and has taken on a range of forms, from the anthropomorphized Disney wildlife film shorts of the of the mid-twentieth century to the twenty-first century cable animal serials that represent what I like to call the "Savannah Gladiatorial Games." In between, there are many subgenres, each with its own signature and each employing some greater or lesser degree of scientific authority, depending on the intended audience and purpose of the program. Consequently, each generic form conveys a particular set of rhetorical messages, some more exacting in the rigors of production than others, but all geared toward an attempt to bring us closer to nature in some vicarious way. In our high-tech, largely urban and suburban culture, the natural world is seen as something remote and uncommon, and this sense of remoteness contributes to the public's inability to understand nature in terms that aren't corrupted by this orientation. While some nature documentaries try very hard to act as a corrective to this alienation from nature, others perpetuate the myth that nature is ours to conquer, control, and transform into a human image. Yet other programs seem orchestrated strictly for their entertainment value, a kind of reality TV for the wilderness, while still others are written for political, scientific, or educational purposes. All such programs carry ideological assumptions that, when critically unpacked, reveal some very important motives and objectives on the part of the producers, directors, and players in these natural dramas, and provide a fascinating cross section of the American mind-set concerning the natural world and our relationship to it.

While there are seemingly countless cable programs dedicated to animals, there are just as many dedicated to natural phenomena like severe weather and natural disasters. One show, *Whale Wars,* is less about whales per se, and more about the personalities of the ecological soldiers who protect them from the ravages of whale poaching. *The Deadliest Catch,* likewise, tells us virtually nothing about the Alaskan king crab or its behavior (except that it is a difficult species to fish for) but all about the dangers to humans while fishing for them in the Bering Sea under extremely cold and hazardous weather conditions. In both of these shows, the focus is on the drama among the humans—not the animal that has gathered them together towards a common goal. The narrative revolves around such questions as: Will the new deck hand work out? Should we board the whaler or merely try to scare the ship off? Will we reach the catch quota and make a profit? There are other programs that focus on the human theatrics of being in an unfortunate "natural" situation, be it severe weather, an inhospitable environment, or a confrontation with wild animals. This category of programs is one that is not strictly anthropomorphic (assigning to nature human attributes), but anthropocentric, that is, centers on human individual and social troubles in wild environments or under extreme conditions and, most significantly, maps our behaviors and expectations onto natural contexts.

To help theoretically frame this idea of how we receive representations of nature relates to how we, as members of a capitalistic, technological society, tend to also frame the world within terms that reflect the interests of production and consumption. In *Permanence and Change,* Kenneth Burke borrows John Dewey's notion of "occupational psychosis" to explain this concept, noting that "the term corresponds to the Marxian doctrine that a society's environment in the historical sense is synonymous with the society's methods of production" (38). In its most primitive form, occupational psychosis reveals itself through a preoccupation with the main source of food for a self-contained group (Burke uses the example of "tribes"), such that this form of sustenance manifests itself symbolically and conceptually in everything the tribe does. If fish are a staple for a given tribe, fish and fishing become a major—even central—topic of concern running through the culture: art, religion, music, dress, and so on. In more developed civilizations, the occupational psychosis becomes more complex and abstracted, such that members of society are often unaware of the origins of their worldview, despite the fact that they voice that worldview symbolically through their language all the time. If wealth, technology, and ownership are central to our economy, we will routinely express ourselves in terms that reflect these interests, including in our choice of entertainment.

Therefore, it is theoretically important for this essay to notice how the two most dominating American orientations of science and capitalism are philosophically couched in a common assumption about the materiality of the world; both are concerned with the physical, objective "reality" of human existence, and therefore, how nature can be understood and manipulated for physical ends. Nature programming, then, must submit to certain epistemological "truths" that shape how such knowledge is presented in a media venue tethered to an economic imperative that forces nature programming into generic categories for prescribed viewers. Such attitudes have political and educational ramifications for how the general public perceives debates that concern the natural world, how we understand the science behind these debates, and the policies we make to address our most pressing environmental problems.

With the increasing popularity of so-called reality TV in the last decade or more, we can expect that most educationally oriented cable stations like Discovery, The Learning Channel, NatGeo, the Science Channel, and others would have to submit to the demographics that drive cable ratings for all channels. America's occupational psychosis determines the framing of the content for these education channels, which have been pressured to conform to an "edutainment" format that meets the needs and preferences of today's television viewer. The nature shows that air regularly on these stations reflect a conformity to "intense," "extreme," and "ultimate" themes, identifying superlative characteristics in animals, environments, weather, or natural disasters that provide the dramatic backdrop for the program's content. A rather curious example of this kind of framing is a program shown on the History Channel called *Serial Killer Earth,* which is a clear case of an anthropocentric structure pitting humans against nature in a kind of planetary dragnet, such that it represents an anthropomorphizing of the earth itself and all the forces it can summon for human destruction. We need only look at the show's title to see that calling the earth a "serial killer" is bizarrely inappropriate, but is deliberately geared to attracting an audience segment increasingly obsessed with murderers, serial killers, and other social deviants. Strangely, this trend in cable formatting indicates a regression to some of America's earliest attitudes about nature, a time when the first American settlers from Europe saw the frontier as uninviting, hostile, dangerous, and even freakish.

A quick glance at the episode titles and descriptions bears this out further. The episode "Death by Dust Storm" features "apocalyptic dust storms" that "suffocate cities around the globe"; it also features "a tornado chasing a family, nearly crushing them with their truck" and further mayhem as "Mother Nature continues to wreak havoc," as though she were a criminal still at large. In "Mudslide Massacre," a twister "targets" a truck driver in Oklahoma and a volcano "smothers" Indonesian citizens. The verbs used to describe these natural occurrences assign willful actions and motivated intent, but it is difficult to tell just how metaphorically the audience is supposed to take such narrative accounts. Even if viewers see the language only as a metaphorical shorthand, such a framing device elicits a sense of victimhood and helplessness at the hands of a sentient force, thus distorting the true unpredictability of climactic and geological events. While scientists look to climate change as one factor in more frequently severe weather, the cessation of global greenhouse emissions and other environmental measures will never eradicate catastrophic storms, tornados, or earthquakes entirely. The negative personification of physical phenomena promotes an odd association with the natural world as something to be feared and ultimately as something that cannot be stopped. Perhaps the strangest episode title is "When Lakes Attack," conjuring images of lakes becoming animated through a supernatural transformation and striking out against enemy humans in some *Lord of the Rings* epic. The idea that we are at war with nature is implied in "Tornado vs. Airport," as though there has been a deliberate battle arranged to determine a conclusive victor between these two "combatants." The notion that the earth is conscious—and malevolent—seems misplaced in the twenty-first century, harkening back to a time when superstition about natural forces ruled human attitudes about its relationship to us. But of course the most basic aim of such tactics is to increase ratings by attempting to quench American entertainment bloodlust and our fixation on all things violent and "extreme." From a production and time slot perspective, shows like *Serial Killer Earth* must compete with other cable programming that adopts the same base attitude about what it is we want in our entertainment, so nature is transformed into an entity of ruthless evil. In a word, such programming becomes simple product, packaged to conform to the collective associations triggered by our culture of nationalism, ownership, law and order, and war.

The themes of attack, war, and battle reveal the colonial side of our occupational psychosis: Americans' tendency to think in militaristic metaphors. We have wars on everything—drugs, crime, women, poverty, Christmas, even God—and cable TV nature documentarians seem to be tapping into this cultural orientation. Some TV documentaries, such as NatGeo Wild's *Caught in the Act,* are reminiscent of gladiatorial games. The animals are usually exotic (giraffes, hippos, tigers, lions, rhinos) and large, pitted against one another in incongruous ways (a giraffe attacking a rhino, for example). Crossing the generic boundary between nature documentary and high-contact, extreme sports, there is an ancient Roman quality to the spectacle, with its focus on the exotic, the spectacular, and the violent. We are a society that loves to see a fight, and what could be more exhilarating than witnessing two large, wild animals go after one another? Showcased in these episodes are themes like "Clash of the Cheetahs," "Elephant Battleground," "Wild Dog Attack," and "Cannibal Octopus." Most of the footage is provided by amateur photographers who serendipitously happened to be in a prime spot to capture an unusual shot, but often it is of poor quality and compensated for by jerky, quick-cut editing and supplemental footage spliced in. Most episodes are not overly sensationalized, however, and many of the situations that have been "caught" on film are truly unusual or unexpected, like the video of a pride of lions attacking an adult mother hippo and, eventually, its calf (there is another example where a "coalition" of three cheetahs perform a similar assault on a wildebeest). It is uncomfortable to watch, and the narrative accompanying the video is supplied almost entirely by the person shooting the footage (in this case an amateur naturalist photographer living in South Africa) and generally avoids the temptation to moralize. For this series, then, there is an incongruity between interpretive vantage points. Whereas the photographer's narration stresses how unusual just such a spectacle is (lions normally do not attack full-grown hippos) and how surprised he was to have been able to capture it on film, the production mantra for the whole series, according to its website, is that it "teaches us that nature doesn't always play by the rules."

Or consider the footage of a lion attacking a mongoose, a creature perhaps one-fiftieth the size of the lion. The mongoose, caught helplessly in the claws of the lion (which appears to be playing with it more than attempting to eat it), fights back viciously in its terror and takes the lion by surprise. When the mongoose escapes the big cat's clutch, the smaller animal lunges at it until it finds an opening and scurries heroically down a tunnel. The narrating photographer is amazed at the mongoose's tenacity, and declares that "nature always teaches me something new." Amazing as the footage is, again the lesson is consistent with the defining rule of survival—in this case, which was more threatened and which had the most to lose. This should not strike one as particularly "new." For the lion, the mongoose was little more than a morsel, and its casual toying with the small creature indicated its lack of commitment to such a modest meal, as it could have crushed it with its jaws or ripped it open with its claws any time it wanted. For the mongoose, it was a mortal battle for its own existence, and it unleashed a fury borne of the desperation to save its own life. While it is indeed surprising that it escaped, the evolutionary law of the jungle remains unbroken—survive any way you can.

Assigning such rules to the wild is one way of engaging our occupational psychosis, since it reflects our desire to superimpose moral order onto a system that is intrinsically amoral. Steven Jay Gould, in an essay called "Nonmoral Nature," argues that this is a conceptual mistake, since it reflects more about our need to impose ethical meaning onto nature than it does any scientific reality about how nature actually operates (60). But still other popular nature programs of note highlight the preoccupation with warlike scenarios and life-threatening situations. NatGeo airs a program called *Dangerous Encounters,* where herpetologist (reptile specialist) Dr. Brady Barr locks horns with dangerous wild animals like crocodiles, snakes, wild boars, and sharks. Animal Planet features shows like *I Shouldn't Be Alive,* a survivalist drama whereby the ordeals of people who have survived natural horrors are interviewed and their stories are recreated, and *Swamp Wars,* in which, according to Animal Planet's website, "Miami-Dade Fire Rescue Venom One battles the alligators, constrictors, and other lethal animals that threaten South Florida." The Discovery Channel airs programs like *Man vs. Wild,* another survivalist show with host "Bear" Grylls going "face to face with the grueling task of navigating remote locations, sharing invaluable survival strategies along the way." The Science Channel runs *Monster Bug Wars* to emphasize the brutality of the insect world, where "a host of ruthless bugs as bizarre as they are lethal slug it out in real-life battles to the death. Witness epic encounters between swarms of marauding assassins, and vicious one-on-one clashes where only one bug survives."

While such portrayals may make a certain practical sense if cable markets are competing for viewers, it also marks a symptom of social malaise about our collective condition. There is a disturbing pessimism running through our culture that seems to embrace the dark and the unpleasant, at least when it comes to our choice of visual distractions, as is evidenced by the sheer number of horror movies, violent action movies, violent thrillers, and war movies released in any given year. To map this collective fetish onto nature programs seems odd, to say the least, but perhaps the most important question is, what does it do to public perception about nature when it is portrayed as a battleground, or on a more personal level, a sentient fiend bent on human destruction? As a symptom of limited scientific literacy and misinformation about scientific discoveries, it appears that programs like *Serial Killer Earth* and *Swamp Wars* are exacerbating an already perilous condition by treating the human-nature relationship as a warlike struggle for dominance instead of as a reciprocation, a kind of symbiosis between human and environment that contributes to the health of both. On a primal level, it is not hard to understand this attitude, since harsh environmental conditions, unpredictable climate, and violent natural forces have always been part of the challenge to our survival, harkening back to a more ancient occupational psychosis. (It is little wonder that, extending from this, primitive and modern religions alike have attributed to natural disasters a sign of a god's displeasure or a manifestation of God's will.) But what the more militaristic man versus nature metaphor suggests is a rationalization for our control over nature, not a capitulation to the gods or a recognition that these powerful forces are part of our natural condition, not a separation from it. In typical American binary fashion, our relationship with nature—with the earth—is a battle that must have two sides, a front, and an objective. This is neither a superstitious attitude nor a strictly rational one, but it has an internal logic given the assumptions implicit in the militaristic framework that contains the relevant anaologies (we fight to win, there is a good guy and an evil enemy, there is a threat that must be preempted, we must summon our technology, victory equals dominance).

Perhaps one of the main reasons such representations have potentially hazardous outcomes is linguistic, that is, pertaining to aspects of our language system in which we have lost the capacity to distinguish from the purely literal; hence we mistake the metaphor for the thing itself. According to Chris Hedges, author of *Empire of Illusion,*

> We are a culture that has been denied, or has passively given up, the linguistic and intellectual tools to cope with complexity, to separate illusion from reality. We have traded the printed word for the gleaming image. Public rhetoric is designed to be comprehensible to a ten-year-old child or an adult with a sixth-grade reading level. Most of us speak at this level, are entertained and think at this level. (44)

Hedges's statement may help explain why the producers of cable television nature shows have opted to portray natural phenomena in such a blatantly uneven and reductionistic way. By conflating everything to resemble some familiar type—celebrities or infamous criminals, for example—modern mass media has eschewed complexity of thought in favor of something everyone can "relate to." This becomes a problem for functional (not to mention scientific) literacy, which Hedges documents as being in serious trouble in the US. According to his estimates, nearly one-third of the US is illiterate or barely literate (unable to read above a fifth-grade level). Hedges explains that "the culture of illusion thrives by robbing us of the intellectual and linguistic tools to separate illusion from truth. It reduces us to the level and dependency of children. It impoverishes language" (45). Our linguistic and rhetorical deprivation has transformed the American citizen into someone who is engaged only by something familiar or something that can be easily and consistently mapped onto a personal belief system in some literal way. If the sophistication of literacy necessary for critical thought has been compromised or systematically stunted in the way Hedges claims, the problem is ultimately a failure of education in the face of overwhelming media mediocrity, and it explains why so many people make decisions that are against their own best interests and apply these same bankrupt decision-making patterns onto their choice of entertainment and their attitudes about nature. It also explains why edutainment options are so exasperatingly limited. If a program doesn't resemble other recognizable formats very closely, it will not get watched because that would require a rhetorical acumen that simply doesn't exist for the average American. If nature is not framed as a competition, a war, a crime, or a pugilistic conflict, chances are (so the logic goes) that cable programs dedicated to nature themes will fail.

A linguistic inadequacy as severe as Hedges describes makes producing any television program a simple matter of plugging certain details into a boilerplate formula, but even the details are remarkably alike. That people can watch bland, indistinct programming episode after episode means that, in Hedges' words, "we become trapped in the linguistic prison of incessant repetition" (49), and this repetition is seen at every site of the mainstream media, whether in programming, advertising, news, or sports. For those who care to diverge from such generic categories and view something on one of the "education" channels, they will often find only a difference in content, not presentation. Personalizing nature and its forces is like getting to know the "characters" on a reality TV show—characters who are also blandly generic. We have an opportunity to "take sides" and pass judgment on humans, animals, and nature all at once. Scientific fact, logical coherence, and critical literacy become the casualties under such conditions, because there is no opportunity (or need) to employ them.

Paraded before the viewer in the battlefield nature narratives I've been discussing is the string of experts, some of whom are genuine, others a bit more dubious. This is of course intended to lend the narratives credibility, but the way expertise is employed by the producers often feels perfunctory. If the narrative involves a tornado in a program like *Serial Killer Earth,* the show may interview a meteorologist who gives us general information about tornadoes—how powerful they are, how unpredictable they are, what conditions are necessary for tornadoes to form, the kind of damage they can cause, and so on—but such experts rarely comment on the content of the central narrative that is the main part of the show. They are there for lexical reference only, and they function as the arbiters of trivia about the phenomenon du jour. The inclusion of such experts actually contributes to the illusion instead of providing a skeptical counterdiscourse for the framing of the narrative. Credentials for experts are often not mentioned or suspiciously vague, but in a culture that thrives on the illusion media manufactures for us, in a narcissistic need to see ourselves in everything we digest, all opinions become equally valid as long as they match our own expectations. Hedges notes: "When opinions cannot be distinguished from facts, when there is no universal standard to determine truth in law, in science, in scholarship, or in reporting the events of the day, when the most valued skill is the ability to entertain, the world becomes a place where lies become true, where people can believe what they want to believe" (51). Experts, under these conditions, become mere window dressing for the legitimacy of the narrative, no matter how sensationalized, exaggerated, or otherwise distorted, to create the militant tone necessary for our "war with nature."

While it is not my intent to condemn these programs as blatant propagators of out-and-out lies that contribute to the eradication of an enemy called nature, there is a deception taking place in these narratives about the dangers we actually face and the causes behind them. One effect of the incessant repetition mentioned earlier is that we are caught in the illusion that the world is far more hazardous to us than it really is. The large number of programs, movies, and TV series showcasing serial killers may lead one to believe that serial killers are lurking around every corner; likewise, the number of programs detailing the catastrophic experiences of those caught in violent natural maelstroms may make us want to avoid going outside. There is also a solipsism in the idea that natural events are staged against humans for human entertainment, as if natural phenomena auditioned for the title of "most extreme" in order to satisfy the viewer's voyeurism in watching people tormented by bad situations. When entertainment and education are conflated, the result can be the pervasive dissemination of bad impressions created by distorted information that may do more harm than good if people cannot distinguish those aspects which are sensationalized for entertainment effect from those that are intended to be instructional. Compounding this distortion further is the ever-increasing reliance on special effects and CGI techniques to augment those components of a program that are more cumbersome (or impossible) to reconstruct using more traditional filmic methods. Media and cultural studies scholar Phil Bagust observes that the "nature documentary as a 'screen genre' and an 'industry sector' has begun to respond to commercial pressures to entertain a youthful, special-effects literate, computer-game playing and blog-empowered audience that has been socialized in a globalized world of rich, spectacular, kinetic, and often violent 'virtual geographies'" (213).

Special effects are so prevalent in all programming these days that one should not infer that they are reserved only for cable nature programs, but they do have a unique effect when applied to this genre. Special effects are as old as the camera itself and have frequently been employed in documentaries going back to the earliest moving pictures. The camera, however, has always been touted as an instrument of science, and as such, photography has enjoyed a privileged reception when it comes to its apparent realism in depicting the objects under its gaze (215). "A picture is worth a thousand words" and "the camera does not lie" are truisms that reveal our faith in the realistic purity of photographic reproduction. The visualization of subjects through a photographic medium has always created an illusion of intimacy with the subject matter because as a species we favor vision over all the other senses. One need only recall the story of one of the first cinematic displays at a theater, a very short film involving a perspective shot of a train heading straight toward the audience. As the story goes, some members of the audience were so convinced of its realism that they dove out of their seats or bolted for the exit in order to avoid being hit by the photographic image! This reaction does seem odd to us today, as we are so accustomed to the virtual windows of the theater or the ubiquitous television and computer monitor that we would never panic at the false impression of a cinematic train, but it does speak to the power of photographic media to summon such "magic." And the realism of early photography was cartoonish by today's standards—the grainy, black and white film used back then hardly even registers with us as photography today, yet we indulge in our own illusions, seeking that which we perceive as more and more "realistic." The realism we recognize, however, is of an unusual order. CGI is used so much in film and television that we have confused its sleek, glossy finish with how we experience the world with our own senses. The "realism" can actually be attributed to the computer enhancement of colors, shapes, depth, and motion that we would never feel when making physical, sensual contact with the actual world around us. The use of color enhancement techniques is especially deceptive; the colors we see on high-definition televisions or computers, for example, are actually far more vivid than what we would see if we were viewing the subject directly. Our eyes register the colors of a computer interpretation of its target image, colors we mistake for the ones actually being recorded. The effect is a sense of reality that is more intense than the visual reality we experience when viewing the world.

To complicate matters further, there has been what Bagust calls a "blurring of boundaries" in contemporary television documentaries that creates a tension between the assumed objectivity of the documentaries and the need to acknowledge the viewing preferences of an audience that seeks to be entertained. As he puts it, "with the arrival of new economic imperatives and new digital technologies of representation, not only have the barriers between 'objective recording' and 'popular entertainment' collapsed but so has 'the fixity of the relationship between signified and signifier supposed by realism'" (217). That is, the relationship between the subject being recorded and the person doing the recording is no longer distinct (we see this in so-called gonzo or POV techniques), as was the case with more traditional assumptions regarding the faithful and unstained reproduction of reality, and the audience is perhaps only vaguely aware of this new dynamic. One of the questions that necessarily arises from this shift is what is the threshold between fact and fiction whereby a program can still be considered a documentary? While the events in *Serial Killer Earth* are based on personal histories, they are dramatized to a degree where strict journalistic facts become far more pliable—and questionable. How should the audience determine which aspect of the portrayal should be taken as factual, which are embellished or dramatized, and which are hypothetical or even fictional? The degree to which audiences today are able to negotiate these differences is hard to say. Sociologists have one measure, whereas television producers, though perhaps relying on certain sociological determiners, tend to run by strict numbers and stats. Who watches a program and how often is far more important in the for-profit sector of cable television than whether or not the message being sent is properly interpreted.

The effect is similar among nature programs that rely heavily on a polished presentation over more substantial content, and this includes all of the shows mentioned here. The generic categories of nature program and reality TV, I have suggested, are becoming increasingly blurred. According to Daniel Beck et al., this blurring has occurred with documentaries generally, and we can trace a history of its development by looking at programs like *Candid Camera,* which was one of the first reality TV programs—in fact, one of the first TV programs, period, first airing in 1948—that modeled an attempt to bring "real" situations to life using "ordinary" people (9). From this early example, we are already witnessing an overlapping of television fact and fiction through a contrived situation designed to get a pseudo-sociological response. Beck breaks these genres down further by tracing other television categories that have historically been either fact based or fiction based, whereas others like crime shows, talent shows, game shows, and documentaries "are seen as a mix of authentic and fictional elements" (17). One of the complications that results when this mix appears in nature programs is that "the viewers have to negotiate the paradoxes and contradictions inherent in the genre and to reconcile the tension between what is subjectively real and fictional" (17). The effect may in fact be more acute for nature programming because the situations, places, and wildlife are often alien to our usual understanding of the natural world. In a typical reality TV show we have some common point of reference: we cook, we have friends, we use products, we are familiar with stores and may even run our own; but we are not so accustomed to camping in a rain forest teeming with hazardous or even deadly life. We are not in the habit of being caught in an earthquake or run out of our homes by a volcano. Again one might conclude that the intent of presenting "reality" is seriously compromised by these factors, the unintended consequence being that the audience has a warped sense of the significance of geographical spaces and events, or of foreign habitats or the species within them, or of our interconnectivity to them.

Man vs. Wild, for example, is a survivalist's fantasy that taps into the American vision of masculinist values: the lone man in a hostile environment, carrying with him only the barest of necessities to combat the malicious elements, the harsh landscape, and the lack of food and water. Sometimes Bear Grylls does not even have a source of fire, or must eat anything containing protein—insect larvae, chick embryos from partially incubated birds' eggs, beetles, raw fish or crustaceans, worms—or he must recycle his own urine in order to keep from dying of thirst. The reality of his peril is of course considerably lessoned if we consider that he is obviously not alone, and it is unlikely that his camera crew or support staff are enduring the same hardships as he is, providing him with a convenient safety net. The conditions he is describing are "real" enough as far as the physical and biological science of it are concerned, but they are staged to demonstrate a particular survival strategy and therefore more closely reproduce boot camp than any situation most of us (or he) will ever accidentally encounter. Shock value seems to be a mainstay for this program, especially when it comes to what Grylls is "forced" to eat. But he is in no actual danger unless something goes terribly unrehearsed—like the daredevil's bane of decades past—defying the script and man's will against natural forces.

This does in fact happen, as in the 2006 death of Australian Steve Irwin, aka The Crocodile Hunter. Though the rumors immediately circulated that Irwin was killed by a croc, he was in fact impaled by a stingray while making the ironically titled documentary, *Ocean's Deadliest.* Irwin was energetic, flamboyant, and entertaining, and in many ways blazed the path for personalities like Bear Grylls to be a popular success. One glance at Irwin's website is all the evidence we need to see the conflation of edutainment and commercialism in action. The site reads like a billboard for a Florida reptile house, and it is difficult at first to find informational content amid the overwhelming presence of ads for Croc Hunter products like shirts, toys, books, vacation packages, or DVDs.

And Irwin's case is interesting for other reasons. His website biography reports that he is a naturalist, a herpetologist, and a conservationist, all indicating that he has formal degrees in the biological sciences. In fact, he does not, but received his experience with animals by "studying and caring for animals at his parents' wildlife park, which is now known as the Australia Zoo" ("Steve Irwin"). Credentialing for a television celebrity is obviously different than it is for a scientist or a professor, requiring only practical experience and no formal study or college education. But unless one actively sought out this information about Irwin, one might assume that he has the formal education necessary to be an authority on exotic and dangerous animals. Bear Grylls, likewise, has no formal college degree but served in the British Special Air Services, climbed Mount Everest, has a black belt in karate, and is an "avid" skydiver. In the American mind, such a resume eclipses any "book learning" that most professionals would view as imperative for being considered an expert. In addition to this autodidacticism, both Irwin and Grylls create personae akin to that of the thrill seeker, not the scientist, and this resonates with an audience that insists on action over instruction. Also, neither of these men are American, and their accents have a beguiling effect on their ethos that Americans seem to respond favorably to. Australia has had a special place in the American heart ever since the 80s Crocodile Dundee craze, and Brits have always been synonymous with culture in American lore. Irwin and Grylls personify the rugged man of the wild and the explorer mythos, intrepid with self-assuredness and that elusive quality assigned to such men, charisma. They are performers, first and foremost, manifesting a role that is ideally suited for the act in which they are appearing, specifically groomed to occupy a unique cable niche.

And such qualities mesh well with the man vs. nature metaphorical frame, since they are the same qualities we would expect from our best and bravest (if not brightest). If our relationship with nature is to be portrayed as warlike, the soldier persona maintains a certain metaphorical consistency, and Irwin and Grylls, while not soldiers, certainly do emote the same soldierly ethos through their daring, their willingness to engage any threat, their mercenary spread to exotic locations, and their ability to survive the harshest of conditions in fulfillment of their mission. The fine line between science and sensationalism, between the pursuit of dangerous animals for biological knowledge and the display of a glorified circus spectacle, is carefully walked by these performers, and there are elements of both. Irwin, for example, usually had a reason for meddling with creatures, but it was not always clear whether it was for research and conservationist purposes or just for kicks. Grylls's stated purpose is to illustrate "survival skills," but again, for the average viewer, his program taps into a masculinist state-of-nature daydream far more than it does into any bona fide need to know such things. Again we see nature entertainment as a *product*—a distinctly commercialized thing to be consumed, a franchise to be capitalized on and expanded. Just as Disney did before them, the anthropocentric nature programs have recognized that giving the audience what it wants—by tapping into ideological orientations like war and conflict that they already possess (a distinctive feature of our occupational psychosis)—is more profitable than representing nature from the perspective of academic biological science.

The programs I have been discussing here represent an educational opportunity that has not, unfortunately, been well fulfilled. Because they are so popular, it is important for the watching public to be vigilant about how they interpret what they are seeing. While I do not think that the American public as a whole is nearly as naïve about how the media both confirms and influences its attitudes as some have suggested, I do think that we are witnessing the need for a higher literacy in technologically delivered information systems like contemporary nature programs. So far, we have been so eager to rush headlong into the "information age" that we have overlooked the need to decipher the overwhelming amount of information we can access. "Technological literacy," as the term is commonly used, means only the knowledge of how to operate new technology and apply it; it does not tend to refer to the means by which new information delivery systems repackage information, create facts and factoids, history, data, and indeed knowledge itself, or how more traditional sources like books and libraries can greatly supplement click-of-a-mouse information access. As a critical tool necessary in the twenty-first century, such "rhetorical literacy" as I am advocating would include far more instruction on all levels of language structure; close critical readings of popular texts, including cable nature programs; training on how logical arguments are constructed; utilizing existing knowledge and making new knowledge; and examining how people, agencies, corporations and other institutions all have rhetorical reasons for presenting knowledge in a preordained way.

When it comes to nature programming as a technological source of information, cable programmers and producers could aid in rhetorical literacy as well; they might, for example, emphasize what role we can play in our own environmental stability. And while no actions will ever prevent blizzards, hurricanes, earthquakes, floods, or other natural catastrophes, actions to make our biosphere healthier can help reduce the frequency of many of our most common disasters while also providing realistic countermeasures to actual threats. They might help us understand the basics of survival under real circumstances rather than indulge our voyeuristic tendency to demand shock and awe in our edutainment. I have discussed only a few of the many programs that cable television now airs and only a few of the methods that are used to construct a subgenre of nature show that represents one slot in the lineup. These shows, however, reveal something broader about American priorities because of their popularity and ubiquity, and they may present certain social, political, and environmental hazards to an uninitiated public.

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Chapter 2

Steven Pinker and the Scientific Sublime: How a New Category of Experience Transformed Popular Science

Alan G. Gross

Abstract

This chapter argues that a well-respected experimental psychologist, Steven Pinker, burst upon the scene with his first book, *The Language Instinct,* a masterly performance that made us feel that our unique ability to speak and understand language was a daily miracle linguistic science had completely unraveled. His second popular science book, *How the Mind Works,* was another blockbuster; it went beyond his area of immediate competence, presenting us with a completely worked-out computational theory of mind. *The Better Angels of Our Nature* reinterpreted history, insisting that, contrary to popular belief, violence had diminished over time. Every one of Pinker's major works shared a single overriding assumption: science could be relied on to shed significant light on subjects far removed from the laboratory or the observatory; science could astonish us by its revelations about language, about the mind, about human behavior generally, and about violence in particular. The scientific sublime is invoked and evoked in each of these cases.

Although the rhetoric of science has become a vigorous subfield within rhetorical studies, the rhetoric of popular science has been largely ignored. Popular science books and essays create a formidable barrier to scholars in the humanities: their study involves the knowledge of science in fields as diverse as myrmecology and mathematical biology. There is a second problem, one I have tried to face. Despite a half century of effort on the part of its scholars, rhetoric has never really shed its pejorative connotations. In my latest project, *The Scientific Sublime: How Popular Science Unravels the Mysteries of the Universe,* to be published by Oxford University Press, I felt I was relatively safe concerning my knowledge of science; after all, I had been in the field for a quarter century. But the pejorative connotation of rhetoric gave me pause. Calling my work *The Rhetoric of Popular Science* and employing rhetorical terminology explicitly seemed unnecessarily to narrow my audience. This avoidance did not mean that I would avoid rhetorical analysis; I just wouldn't call it rhetorical analysis. This chapter on Steven Pinker is a rhetorical analysis; indeed, given that it deals with a master rhetorician, how could it not be?

In *The Scientific Sublime,* all the authors with which I deal—Steven Pinker, but also Richard Feynman, Steven Weinberg, Brian Greene, Lisa Randall, Stephen Hawking, Rachel Carson, Stephen Jay Gould, Richard Dawkins, and E. O. Wilson—employ a single, overarching rhetorical concept, the sublime, first identified in late antiquity in a treatise by Longinus. *On the Sublime* claimed that certain literary passages generated awe, for example: "God said, Let there be light, and there was light." Awe was an emotion Aristotle did not mention in his *Rhetoric;* still, awe can easily join the emotions he does mention. When, after having disappeared for centuries, *On the Sublime* reappeared in early modern Europe, it began a cultural journey of some significance; it led to an expansion from literature to nature, and from nature to science. In the eighteenth century, there developed a scientific sublime, a category of experience that generated a sense of wonder at the discoveries of science. The sublime, I claim in this chapter, is a persuasive resource that Pinker and his fellow scientist-popularizers consistently employ.

Pinker employs this persuasive resource to amaze us with the facts and theories of science. On these topics his rhetorical skills, consistently energized by the sublime, rightly impress us with his ability simultaneously to inform and to convince. But Pinker also uses these skills and this persuasive resource to advocate for positions on which there is deep and long-standing professional disagreement. Of course, Pinker is entitled both to hold and to convey his professional stands to his readers. But it is also possible to feel that in these instances his employment of the scientific sublime might well mislead them because opposing sides are not given a fair shake. Readers might come to believe that these stands and opinions are not just stands and opinions.

The Scientific Sublime

In his *History of Astronomy* Adam Smith provides us with the first satisfactory analysis of the psychology of the scientific sublime, a new category of experience derived from Longinus. According to Smith, a path to the sublime opens when a spectacular natural event—an eclipse of the sun, for example—captures our attention and causes

> the imagination and memory [to] exert themselves to no purpose, and in vain look around all their classes of ideas in order to find one under which it may be arranged. They fluctuate to no purpose from thought to thought, and we remain still uncertain and undetermined where to place it, or what to think of it. It is this fluctuation and vain recollection, together with the emotion or movement of the spirits that they excite, which constitute the sentiment properly called *Wonder,* and which occasion that staring, and sometimes that rolling of the eyes, that suspension of the breath, and that swelling of the heart, which we may all observe, both in ourselves and others, when wondering at some new object, and which are the natural symptoms of uncertain and undetermined thought. What sort of a thing can that be? What is that like? are the questions which, upon such an occasion, we are all naturally disposed to ask. (Smith, *Essays* 39)

Two other senses of wonder are evoked when we answer these questions. The first is the discovery of a pattern in nature, a sense not noticed by Smith: the Babylonians could predict eclipses but not explain them. Such explanations evoke Smith's other sense of wonder. His example is the satisfying astonishment that greeted Ptolemaic astronomy on its introduction in ancient Greece, a system that made mathematical sense of the heavens:

> If [the system of concentric spheres] gained the belief of mankind by its plausibility, it attracted their wonder and admiration; sentiments that still more confirmed their belief, by the novelty and beauty of that view of nature which it presented to the imagination. Before this system was taught in the world, the earth was regarded as, what it appears to the eye, a vast, rough, and irregular plain, the basis and foundation of the universe, surrounded on all sides by the ocean, and whose roots extended themselves through the whole of that infinite depth which is below it. (Smith, *Essays* 56)

Achievements such as this cannot be appreciated by ordinary folk: the problems they solved would never have occurred to them (Smith, *Essays* 45). Moreover, they would regard the efforts to find a solution as worthless because without practical application:

> It is in the abstruser sciences, particularly in the higher parts of mathematics, that the greatest and most admired exertions of human reason have been displayed. But the utility of those sciences, either to the individual or to the public, is not very obvious, and to prove it, requires a discussion which is not always very easily comprehended. It was not, therefore, their utility which first recommended them to the public admiration. This quality was but little insisted upon, till it became necessary to make some reply to the reproaches of those, who, having themselves no taste for such sublime discoveries, endeavor to depreciate them as useless. (Smith, *Sentiments* 272)

For Smith, it is in Newton's *Principia* that these abstruser sciences culminate:

> Can we wonder then, that it should have gained the general and complete approbation of mankind, and that it should now be considered, not as an attempt to connect in the imagination the phenomena of the Heavens, but as the greatest discovery that ever was made by man, the discovery of an immense chain of the most important and sublime truths, all closely connected together, by one capital fact, [that is, gravity], of the reality of which we have daily experience. (Smith, *Essays* 105)

C. P. Snow gives us another example—the second law of thermodynamics, the principle that all closed systems eventually run down: "it has its own somber beauty; like all major scientific laws, it evokes reverence" (Snow 72). Of course, Snow cautions, "it needs understanding, which can't be attained unless one has learnt some of the language of [science]" (72). This is exactly what scientist-popularizers hope to communicate to a mass audience. Unlike well-known popular science physicists like Stephen Hawking, Steven Weinberg, Brian Greene, and Lisa Randall, however, Steven Pinker does not limit himself to the abstruser sciences. He sets as his goal the evocation of our sense of wonder at the latest discoveries in linguistics, psychology, and history, his own and those of others. To do so, he employs a category of cultural experience Adam Smith applied to science itself, the sublime.

The Language Expert

In the latter half of the tenth century, the Anglo-Saxon monk, Aelfic, wrote a homily on daily miracles, the power of God to sustain the universe moment by moment, a marvel hidden in plain sight:

> God hath wrought many miracles and daily works; but those miracles are much weakened in the sight of men, because they are very usual. A greater miracle it is that God Almighty every day feeds all the world, and directs the good, than that miracle was, that he filled five thousand men with five loaves: but men wondered at this, not because it was a greater miracle, but because it was unusual. Who now gives fruit to our fields, and multiplies the harvest from a few grains of corn, but he who multiplied the five loaves? The might was there in Christ's hands, and the five loaves were, as it were, seed, not sown in the earth, but multiplied by him who created the earth. (*The Sermones Catholici* 185)

Steven Pinker strives to be the Aelfric of linguistics, to explore with us the ordinary miracle of language acquisition and use. He labors successfully to make clear and cogent to the general public the recondite insights of Noam Chomsky, the linguist who claimed that the intricate patterns that characterize the world's languages, their differing surface structures, were the consequence of a common core, a deep structure, a universal grammar, the generator of all languages. The success of *The Language Instinct,* and of Pinker's two subsequent books on language, was due in part to the clarity of his exploration of this phenomenon. But it is not this clarity that makes his work compelling; it is his evocation of the scientific sublime, a revelation that shows us that something we all possess—something we all take for granted—is a daily miracle that repays our careful scrutiny, an examination that reveals a human capacity that science lays bare and explains.

Pinker reveals linguistics as the science that shows us just how much of a miracle language is, and the wonder that is evoked when we understand how language works. All of us routinely turn its storehouse of words and rules into an infinite number of possible sentences, each newly minted for the occasion. Because we achieve these articulate heights by the age of three, we can't have learned language just from hearing our parents speak. We must have been primed in advance; each of us must have an all-purpose language generator packed inside our skulls. Of course, we all speak different languages: French children learn French, American children, English. But this is only because a universal grammar, an innate capacity, made learning any language possible. It is this grammar, modified to accommodate the rules of particular languages, that generates the sentences we speak. If American, we learn that almost all adjectives precede their nouns. Americans say, "the blue ink." If French, we learn that adjectives generally follow their nouns. The French say "l'encre bleu." Modern linguistics tells us that these differences obscure commonalities, persistent patterns that are themselves a source of wonder; it also reveals the generator of these patterns, their explanation, a source of wonder even more impressive than the first.

Modern linguistics deals not only with the miracle of language, but with the miracle of speech. If we had language, but not speech, we could still communicate effectively: the profoundly deaf do it every day. Most of us, however, rely on our ability to convey our thoughts through the sounds we make. This capacity to form sounds into words and sentences and to perceive those sounds as words and sentences evolved in coordination with the universal grammar, a simultaneous development so impressive it gives some philosophers pause when evolution is given as their explanation. Even Pinker, a man who will insist in later work that he knows how the mind works, doubts our ability to understand human speech recognition: "The human brain . . . is a high-tech speech recognizer, but no one knows how it succeeds" (Pinker, *Instinct* 183); in fact, "no system today can duplicate a person's ability to recognize both many words and many speakers" (Pinker, *Instinct* 162). Pinker also explains why the speech generator is just as miraculous as the speech recognizer:

> First, one of the six speech organs is chosen as the major articulator: the larynx, the soft palate, tongue body, tongue tip, tongue root, or lips. Second, the manner of moving that articulator is selected: fricative, stop, or vowel. Third, configurations of the other speech organs can be specified: for the soft palate, nasal or not; for the larynx, voiced or not; for the tongue root, tense or lax; for the lips rounded or unrounded. Each manner or configuration is a symbol for a set of commands to the speech muscles, and such symbols are called features. To articulate a phoneme, the commands must be executed with precise timing, the most complicated gymnastics we are called upon to perform. (Pinker, *Instinct* 171)

Phonemes form words, those groups of letters separated by spaces on the printed page. In fact, those spaces exist only on the page: in reality, speech is a steady, seamless stream of sound. While our ears and our brain experience this stream, we hear sentences made up of words, an extraordinary transformation. That a three-year-old can have mastered this mental and physical feat is truly astonishing.

Each language also has its phonetic fingerprint, the growl of German, the lilt of French. This is how the great comedian, Sid Caesar, seemed to speak German or French while actually speaking nonsense. Pinker quotes a woman who produced under hypnosis the following pseudo-Slavic nonsense: "Ovishta reshra rovishta. Vishna beretishti? Ushna barishta dashto" (Pinker, *Instinct* 172). Once the shape of a language is firmly embedded, however, the pattern is resistant to change. Every Chinese child speaks unaccented Chinese. But few American adults can learn to speak unaccented Chinese: almost all speak it with an American accent. Although the language is clearly Chinese, the pattern of sounds that speakers generate is tainted indelibly by their native tongue. "Here is Jack and the Beanstalk" with an Italian accent: "Unans appona taim uase disse boi. Neimmse Giacche. Naise boi. Live uite ise mamma. Mainde de cao" (Pinker, *Instinct* 172). While most adults cannot go from language to language and sound like natives, many actors can. In the old-time radio show, *Life with Luigi,* J. Carrol Naish and Alan Reed adopted an Italian accent, transforming "Jack and the Beanstalk" into "Giacche enne Binnestauche."

Just as there are rules for grammar, there are rules that govern phonetics, determining how features are arrayed into phonemes and words. In the written language, many verbs end in "ed" in the past tense: *slapped, jogged, bedded.* While these endings are all spelled the same way, they do not sound the same way. In *slapped* the "ed" is pronounced "t"; in *jogged* it is pronounced "d"; in *bedded* it is pronounced "ed." In each case, the reason is phonetic, and a rule applies. After an unvoiced vowel, we get "t"; after a voiced vowel, we get "d"; after a "d" (or a "t"), we get "ed." In each case, the constraints of our speech apparatus determine our pronunciation.

But if this is so, why do we persist in tolerating the gap between pronunciation and spelling? Why not spell words just the way they sound: *slapt, jogd, bedded?* Isn't English spelling irrational? Certainly, it does not make sense to have a "b" in debt or a "k" and a "gh" in knight. They are there only because history put them there: the "b" because of a mistaken analogy with Latin, the "k" and "gh" because these letters were once pronounced. The arrival of dictionaries regularized spelling and fixed these oddities, seemingly forever. As Pinker points out, however, phonetic spelling would only make things worse. We would spell "courage" differently from "courageous," "muscle" differently from "muscular." The fact is that "writing systems do not aim to represent the actual sounds of talking, which we do not hear, but the abstract units of language underlying them, which we do hear" (Pinker, *Instinct* 191).

Taking Sides

Pinker's three books on language introduce us to two lively controversies in linguistics: the origin of language and the origin of concepts, the ideational forces behind language. I have already noted that Pinker's greatest theoretical debt is to Noam Chomsky, the most influential advocate of the theory that language is generated by a set of rules built into our brains. Chomsky's 1957 *Syntactic Structures* created a revolution in the study of language. Two years later, in a devastating review of a behaviorist approach that language is a form of conditioning, B. F. Skinner's view in his *Verbal Behavior,* Chomsky reminded us of his alternative, one that would prove fruitful indeed. He saw the grammar of a language as a mechanism that generates sentences in the way that a deductive theory generates theorems. For him, linguistics should be viewed as a study of the formal properties of such grammars. With a precise enough formulation, this general theory could provide us with a uniform method for determining how sentences are generated, used, and understood. In short, it should be possible to derive from a properly formulated grammar a statement of the integrative processes and generalized patterns imposed on the specific acts that constitute an utterance (Chomsky, "A Review" 55–56). As Newton reduced the workings of the universe to the law of gravity and the laws of motion, Chomsky reduced language to the operation of this grammar. It was awe inspiring when Chomsky first brought these ideas before the public; it is still awe inspiring. The trouble is, it might not still be science; it might not be true, an uncomfortable fact of which Pinker is well aware.

Despite its tremendous success and legion of followers, the universal grammar met with almost immediate challenges from many quarters (Harris). And these challenges have not abated. Three decades after Chomsky's initial revelation, for example, David Rumelhart and James McClelland proposed an alternative to his rule-based system. There were rules of a sort, they said, such as the rule that most past tenses in English end in "ed." But these were generated not by a universal grammar, but by the experience of children with the spoken language. It was an experience represented in neural networks by an increase in the probability of the "ed" ending, the ending of regular verbs. Of course, irregular verbs also have to be learned. Some come in patterns: for example, *slept, kept, wept,* and *crept,* and their phonological analogues, *leapt, prepped.* A few others, frequently occurring oddballs, such as *was, go, went,* must be learned by rote.

In this research program, connectionism, language learning is just learning. Rumelhart and McClelland summarize their view:

> We have, we believe, provided a distinct alternative to the view that children learn the rules of English past-tense formation in any explicit sense. We have shown that a reasonable account of the acquisition of past tense can be provided without recourse to the notion of a rule as anything more than a description of the language. We have shown that for this case, there is no induction problem. The child need not figure out what the rules are, nor even that there are rules. The child need not decide whether a verb is regular or irregular. There is no question as to whether the inflected form should be stored directly in the lexicon or derived from more general principles. There isn't even a question (as far as generating the past-tense form is concerned) as to whether a verb form is one encountered many times or one that is being generated for the first time. A uniform procedure is applied for producing the past-tense form in every case. The base form is supplied as input to the past-tense network and the resulting pattern of activation is interpreted as a phonological representation of the past form of that verb. This is the procedure whether the verb is regular or irregular, familiar or novel. (McClelland and Rumelhart 267)

These views are, obviously, a challenge to any rule-based system. Pinker's strategy in rejoinder is to point out the many problems that Rumelhart and McClelland have in accounting for every instance of the past tense. For example, because their model is based exclusively on the sound of words, it cannot account for those that sound alike but have different plurals, words such as *wring* and *ring.* Given this and related difficulties, Pinker feels justified in dismissing "the knee-jerk associations that drive the Rumelhart-McClelland model" (Pinker, *Words* 110). This is the position of Pinker and Alan Prince, whose article dismantled this model, piece by piece. Nevertheless, it turns out that Pinker and Prince "are probably the model's biggest fans" (Pinker, *Words* 117). In *Words and Rules,* Pinker proposes a compromise—a kind of unified theory of linguistics—that, while it applies the Rumelhart-McClelland model to all irregular verbs, applies his own rule-based model to all regular ones. For Pinker, there must be rules for regular verbs.

McClelland is having none of it. There may very well be rules, but they would not have been there in the first place; they would have developed as the outcomes of probabilistic processes:

> We do not claim that it would be impossible to construct a rule-based model of inflection formation that has all of the properties supported by the evidence. However, such an account would not be an instantiation of Pinker's symbolic rule account. In fact, rule-based models with some of the right characteristics are currently being pursued. . . . If such models use graded rule activations and probabilistic outcomes, allow rules to strengthen gradually with experience, incorporate semantic and phonological constraints, and use rules within a mechanism that also incorporates word-specific information, they could become empirically indistinguishable from a connectionist account. Such models might be viewed as characterizing an underlying connectionist processing system at a higher level of analysis, with rules providing descriptive summaries of the regularities captured in the network's connections. (McClelland and Patterson 471)

Like Chomsky's *Syntactic Structures,* Rumelhart and McClelland's initial article has generated a tsumani of empirical research, created by an army of men and women staking their careers on the fruitfulness of connectionist theory. From their point of view, the rule-based program of Chomsky and Pinker may be worse than wrong; it may inhibit our understanding of the nature of language; it may actually mislead us. Linguist Franklin Chang concludes that

> it is possible that the requirement that syntactic knowledge in different languages be instantiated in a common syntactic theory actually hinders the development of explicit models. Ironically, by making fewer assumptions about the universal nature of syntactic knowledge and allowing learning to determine the constraints for each language, we might actually get closer to a universal account of human language behavior. (Chang 392)

Pinker involves his general readers in another controversy about language, the origin of concepts. Clearly, we didn't enter the world with concepts like *trombone* and *electron* inside our heads. On the other hand—and this is the problem—concepts can't be learned. Although we can learn *about* trombones and electrons, we can only do so by asking questions like: What does a trombone sound like? How big is an electron? Such questions assume that we *already* have the concept of trombone and electron in our heads. One possibility—a possibility favored by Pinker—is that we are born with certain basic concepts already in our heads, concepts like *cause* and *effect.* These are innate. Concepts like trombone and electron are acquired, the progeny of some combination of these basic concepts.

There is a problem with this apparently very sensible approach, one that well-respected philosopher Jerry Fodor hammers home. Pinker's solution requires that his repertory of innate concepts be sufficient to define exactly what we mean when we use either trombone or electron in a sentence. But all definitions save the mathematical are as full of holes as Emmentaler cheese. Triangles can be defined; ordinary words cannot. Let's take the verb *paint.* Let's define *paint* as "cover a surface with paint." No, that won't do. If we kick a can of paint over on the floor, we haven't painted the floor; if Michelangelo is working on the Sistine ceiling, he is not painting it; he is painting a picture on it; if he dips his brush into a pot of paint, he is not painting the brush, but preparing to paint the ceiling. The problem is general. *Kill* can't be decomposed into *cause to die.* Although I can cause you to die by not calling an ambulance, I haven't killed you. This problem also has quite a reach: philosopher Edmund Gettier showed conclusively that you can't define knowledge as justified true belief. Indeed, you can't define knowledge at all.

Pinker thinks he has an answer to these difficulties. Fodor has confused definitions with semantic representations. For example, the semantic representation of the verb *paint* would include the idea that *to paint* is the act of an *agent* whose goal is to cover a surface with paint. But this fix is no fix at all. We still haven't dealt with the difference between *I painted the ceiling* and *I painted a picture on the ceiling.* Moreover, what are we to say of *I painted the wound with mercurochrome?* What about the verb *to butter?* Is a person who butters a person who spreads a viscous, yellowish edible substance, not necessarily butter, on another edible substance? Suppose I use butter to soothe a burn? Am I buttering the burn? (Pinker, *Stuff*)

Nobody, it seems, favors Fodor's original or his revised position, one in which he abandons the view that *trombone* and *electron* are innate. For this, he substitutes a mysterious process in which trombones and electrons imprint their concepts on our brains the way ducklings are imprinted from birth with the concept *mother.* But Pinker's solution—alleged semantic representations—is a nonstarter. Indeed, Pinker seems aware of his failure. In *How the Mind Works,* he gives us an example that defies analysis in terms of semantic representation. A bachelor is a man who has never married, right? So is Arthur, who is living with Alice, a bachelor? Is Bruce, who has arranged a marriage simply to avoid the military draft? Is Charlie, who is seventeen and lives with his parents? Is David, who is also seventeen, but on his own and living the life of a playboy? Are Eli and Edgar, homosexual lovers, living together? Is Faisal, with his three wives, a man in search of a fourth? Is Father Gregory? (Pinker, *Mind* 13)

I have no opinion about the relative merits of these opposing positions. More to the point, I do not think I am are entitled to an opinion. First, I lack the knowledge required, and second, even the required knowledge is at present insufficient to achieve closure on the part of the participants. I can hope that experts will eventually agree, and that that agreement will stand the test of time. In the meantime, I have Chomsky and Pinker on the one hand; Rumelhart, McClelland, and Fodor on the other. In each case, Pinker's scientific sublime is generated, not by means of a widely accepted theory but by an interesting hypothesis, supported by apparently solid arguments and apparently convincing evidence.

How the Mind Works

How does the mind work? According to Pinker, all mental capabilities depend on the brain's computational abilities. This is not to say that we are walking around with a laptop between our ears; it is to say, rather, that the brain processes our sensations in a way analogous to the way a computer processes its zeroes and ones. Does the general case obtain? Can we legitimately view the brain as a computer? Whether or not we can, computational theory seems fully to explain certain remarkable characteristics of human vision, a theory that Pinker clearly and incisively expounds, a legitimate evocation of the scientific sublime.

We all face a problem: How do we identify the orientation of shapes rotated in space? According to one theory, we retain each separate orientation in memory; according to another, we are capable of rotating shapes in their own mental space; according to a third, geon theory, orientation doesn't matter—identification is simply a matter of pattern matching. Pinker conducts an experiment to decide which theory is correct. He is a scientist, after all, not just a reporter of science. It turns out that people use all three methods, depending on the circumstances. But Pinker is not finished. He also wants to give us the flavor of his discovery, the sudden insight into the way the visual system works, an experience he calls "my happiest moment as an experimenter" (Pinker, *Mind* 281).

In image rotation, there is an interesting anomaly. While the degree of image tilt generally correlates with the time it takes to identify images, this is not true of mirror images, a result that continues to baffle. Disregarding this persistent puzzle, Pinker and his graduate student start to write up their paper. In it, they speak of a different "strategy" employed for mirror images, a sure indication that they are "clueless" about the real solution to their problem. It is then that "an idea hit" (Pinker, *Mind* 282): it turns out that a two-dimensional shape, rotated around its axis like a chicken on a spit, can always be aligned with its mirror image: the degree of tilt makes no difference. The computational theory of mind chalks up another victory. The scientific sublime has been evoked, legitimately to inform and persuade.

But Pinker is not satisfied merely to explain feats of human vision; he wants also to trace them back to their origin, to endorse an evolutionary theory of mind. Uniformly, he attributes the origin of the incredible feats of which the human eye is capable to selection pressures operating on human variation, a process that begins with our simian ancestors and ends with us. An example is cyclopean vision—our ability to see with both eyes shapes that which cannot be seen with only one:

> Primates evolved in trees and had to negotiate a network of branches masked by a veil of foliage. The price of failure was a long drop to the forest floor below. Building a stereo computer into these two-eyed creatures must have been irresistible to natural selection, but it could have worked only if the disparities were calculated over thousands of bits of visual texture. (Pinker, *Mind* 233)

It is no dismissal of evolutionary theory to say that in this passage it is transformed into an ideology by means of which Pinker generates not science, but science fiction. There is no evidence for the truth of his conjecture. How could there be?

Pinker's unwavering view is that the mind is the product of an evolution that is wholly materialistic. Although he seems blind to the unfortunate implications of this view, he puts his finger directly on their cause, the problem of consciousness, without which morality—the choice of right from wrong—is impossible to imagine:

> No account of the causal effects of the cingulate sulcus [area of the brain] can explain how choices *are not caused at all,* hence something we can be held responsible for. Theories of evolution of the moral sense can explain why we condemn evil acts against ourselves and our kith and kin, but cannot explain the conviction, as unshakable as our grasp of geometry, that some acts are inherently wrong, even if their net effects are neutral or beneficial to overall well-being. (Pinker, *Mind* 561)

It is the philosopher Thomas Nagel who makes the appropriate inference: No theory of evolution can be correct that views it solely as a material process (Pinker, *Mind* 50). If we are conscious, and if consciousness is a consequence of our evolutionary history, then the precursor of consciousness in all its immateriality must have been present at the big bang: "intentionality, thought, and action resist psycho-physical reduction and can exist only in the lives of beings that are capable of consciousness" (Nagel 68).

There is a final problem, one with the computational theory of mind itself. Pinker, a dedicated advocate of this theory, sees the mind as an organ "packed with high-tech systems" (Pinker, *Mind* 4). But surely Jerry Fodor is right to find this analogy between human and natural engineering less than compelling. How, he asks, can Pinker assert how hopeless we are when it comes to building a serviceable robot—one that can put away the dishes—and at the same time contend that we know that the mind works just like a robot's control system? (37). Pinker does not have a theory of how the mind works; he has a model for the way some parts of the *brain* work, a model that passes the test of science. *How the Mind Works* champions a computation theory that is unable to explain why we can use a knife and fork and robots cannot, one that favors evolutionary theory of mind that cannot explain how consciousness evolves from a primal soup of elementary particles. But Pinker's employment of the scientific sublime throughout *How the Mind Works* may easily give his readers the impression that science supports the sweeping claims he sometimes makes.

Violence

In the Rwanda genocide of 1994, as many as one million died, approximately ten percent of the population; in the Syrian civil war, ongoing in 2017, over 400,000 have died, approximately two percent of the population. In the United States, ten percent of the population would mean thirty-two million deaths, two percent over six million. In the face of atrocities so devastating, Pinker's claim in *The Better Angels of Our Nature: Why Violence Has Declined* that violence has declined seems open to question. Yet his ninety-five graphs and tables, strategically placed throughout his book, tell the same story: violence *has* declined. Asked in an interview why an experimental psychologist felt he could write about history, Pinker focused on these very graphs and tables as the heart of his book, defending himself on scientific grounds: "*Better Angels* concentrates on quantitative history: studies based on datasets that allow one to plot a graph over time. This involves the everyday statistical and methodological tools of social science, which I've used since I was an undergraduate—concepts such as sampling, distributions, time series, multiple regression, and distinguishing correlation from causation" ("Steven Pinker"). It is by this means that Pinker proves that your chance of meeting a violent death has greatly diminished over time. The scientific sublime has been properly evoked.

In table 2.1, the death tolls for historical large-scale atrocities are given as two values: estimated toll from historical records and that same toll adjusted to the world's population in the mid-twentieth century (I have rearranged the order of Pinker's original table from a given cause's unadjusted to adjusted rank). The most startling number in this startling list is the 36 million deaths in the An Lushan Revolt during China's Tang Dynasty. Scaled up to account for population growth, we have the mid-twentieth-century equivalent of 429 million deaths, a staggering number greater than the entire populations of the United States and Canada combined, and far greater than the total death toll from both world wars. It would seem that Pinker has indeed discovered an astonishing pattern in human history.

Or has he? Has the sublime, so skillfully employed to convince, really produced a historical truth? Operational definition is surely among the methodological tools of the social science Pinker employs. But neither from his tables and figures nor from his text can an operational definition of violence be derived. Wars and preventable famines are both consequences of state power, but only the former involves violence. Nor is slavery primarily an exercise in violence, though human beings are enslaved as its consequence, and slavery leaves slaves open to violence exercised with impunity. Moreover, Pinker's own figures can be differently aggregated so as to tell another, less optimistic story. Any account of twentieth-century violence must notice that two world wars, Mao's famine, Stalin's persecutions, the Congo war, and the Russian civil war accounted for 147 million deaths, all in only five decades. By contrast, the Mongol conquests (adjusted rank no. 2) resulted in 40 million deaths (278 million equivalent) in 163 years. Indeed, six of the top ten in Pinker's murderers' row of mass violence span more than a century. Moreover, the statistic of 36 million deaths in the nine years of the An Lushan Revolt is controversial, as Pinker admits. That total is based on a highly questionable census taken at the rebellion's end, with the reigning Tang Empire in disarray and greatly shrunk in size. A more conservative estimate is 13 million unadjusted ("List of Wars").

Added to these problems are Pinker's omissions. If Pinker sees slavery as a form of violence, now thankfully eliminated for the most part, why does he omit child labor and child soldiering, two forms of enslavement still with us? Why

Table 2.1 Historical Death Tolls Adjusted to World Population in Mid-Twentieth Century

Unadjusted rank	Cause	Century	Death toll	Death toll: mid-20th-century equivalent	Adjusted rank
4	An Lushan Revolt	8th	36,000,000	429,000,000	1
3	Mongol Conquests	13th	40,000,000	278,000,000	2
9	Mideast Slave Trade	7th–19th	19,000,000	132,000,000	3
5	Fall of the Ming Dynasty	17th	25,000,000	112,000,000	4
15	Fall of Rome	3rd–5th	8,000,000	105,000,000	5
11	Timur Lenk (Tamerlane)	14th–15th	17,000,000	100,000,000	6
7	Annihilation of the American Indians	15th–19th	20,000,000	92,000,000	7
10	Atlantic Slave Trade	15th–19th	18,000,000	83,000,000	8
1	Second World War	20th	55,000,000	55,000,000	9
6	Taiping Rebellion	19th	20,000,000	40,000,000	10
2	Mao Zedong (mostly government-caused famine)	20th	40,000,000	40,000,000	11
12	British India (mostly preventable famine)	19th	17,000,000	35,000,000	12
17	Thirty Years' War	17th	7,000,000	32,000,000	13
18	Russia's Time of Troubles	16th–17th	5,000,000	23,000,000	14
8	Josef Stalin	20th	20,000,000	20,000,000	15
13	First World War	20th	15,000,000	15,000,000	16
21	French Wars of Religion	16th	3,000,000	14,000,000	17
16	Congo Free State	19th–20th	8,000,000	12,000,000	18
19	Napoleonic Wars	19th	4,000,000	11,000,000	19
14	Russian Civil War	20th	9,000,000	9,000,000	20
20	Chinese Civil War	20th	3,000,000	3,000,000	21

Source: Steven Pinker, *The Better Angels of Our Nature: Why Violence Has Declined,* Viking, 2011, p. 195.

does he omit the deaths resulting from America's love affair with the private automobile, the state's decision to exercise its muscle in favor of unsafe over safe transportation, in effect to license a form of violence? These categories show that we may not be less, only differently violent, the victims of new expressions of violence shaped by changing social, political, and economic circumstances.

The questionable aspects of Pinker's claim extend to his explanation. While in the last 200,000 years we have not evolved anatomically, we have, Pinker avers, evolved socially and politically: gradually, reason has triumphed over irrationality. Indeed, "once a society has a degree of civilization in place, it is reason that offers the greatest hope for further reducing violence" (Pinker, *Better Angels* 668). The prospects of a reduction in violence seem particularly bright because we are getting smarter. While it is true that we are getting better at IQ tests, a phenomenon known as the Flynn effect, we cannot infer from this that human intelligence is actually increasing. Flynn agrees: "Can anyone take seriously the notion that the generation born in 1937 was that much more intelligent than the generation born in 1907, to say nothing of the generation born in 1877?" (Flynn 7). The Flynn effect is only about what intelligent tests measure.

In any case, getting smarter does not mean getting nicer. Take practical reason, our ability to deal more and more effectively with manufacturing problems. This is an area where we have undoubtedly improved over time. But the same assembly line that produced Model T Fords made the Holocaust possible. Nor is being smart necessarily correlated with being free from socially harmful bias: Martin Heidegger and Gottlob Frege are two philosophers with deservedly towering reputations: both were antisemites. Ezra Pound and T. S. Eliot were poets and critics of distinction: both were antisemites. Pinker's employment of the scientific sublime throughout *The Better Angels of Our Nature* may easily give his readers the impression that legitimately contestable claims about the betterment of humanity have been scientifically settled.

Conclusion

A well-respected experimental psychologist, Steven Pinker burst upon the scene with his first book, *The Language Instinct,* a masterly performance that made us feel that our unique ability to speak and understand language was a daily miracle linguistic science had completely unraveled. His second popular science book, *How the Mind Works,* was another blockbuster; it went beyond his area of immediate competence, presenting us with a completely worked-out computational theory of mind. *The Better Angels of Our Nature* reinterpreted history, insisting that, contrary to popular belief, violence had diminished over time. Every one of Pinker's major works shared a single overriding assumption: science could be relied on to shed significant light on subjects far removed from the laboratory or the observatory; science could astonish us by its revelations about language, about the mind, about human behavior generally, and about violence in particular. In each of these cases, Pinker's rhetorical skills enhance his subject matter; he makes learning a pleasure. The scientific sublime is legitimately invoked and evoked.

Pinker has become a global celebrity, as his book sales and YouTube videos attest; he has charisma, as anyone can see from any of these videos. He is also a leading figure in a fairly recent cultural phenomenon: a large group of prominent scientists who write best-selling books on science. It takes nothing from Pinker's books to say that they consistently violate a rule that another scientist of note, Richard Feynman, followed in his popular science writing: Never stray from knowledge that could legitimately appear in a textbook for undergraduates as well-established science. While Pinker's frequent violation of this principle in no way constitutes a criticism of his achievement—he has many interesting and provocative things to say on a wide variety of subjects—it does indicate that he should be read with caution. We must treat with skepticism his view that ordinary readers can decide between rival theories of language generation and the origin of concepts, that a computer model can explain how the mind works, and that we live in a safer world because we are smarter than our ancestors. In each of these cases, we may well be prompted to ask whether the scientific sublime has been legitimately invoked and evoked.

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Chapter 3

Architectonic Discourses and Their Extremisms

Barry Brummett

Abstract

This chapter explores the concept of architectonic discourses and the extremisms to which they are prone. Taking Aristotle's distinction between discourses that offer sure and certain systems to guide distinctions and those discourses (primarily rhetoric and dialectic) that manage decisions that are contingent and uncertain, the author explores a range of discourses that have historically claimed to be architectonic, or ruling, discourses. The dangers of extremism in such discourses are illustrated in a brief analysis of a website opposing childhood vaccinations.

Popular culture and popular discourse are full of claims, implied or explicit, about what we can know and how we can know it. Religious zealots claim a confident certainty for their beliefs, while committed atheists claim an equally confident status for their rejection of spiritual belief. Scientists and medical personnel issue *ex cathedra* opinions about the flu, Ebola, and other diseases. Business schools make a nice return on the promise of dependable systems for knowing how to lead. Education schools claim to possess reliable methods for imparting knowledge. Television is full of pundits who will give you the right way to diet, to raise children, or to lose weight. Everywhere we are faced with choice, and everywhere we are offered ways to make those choices with confidence. And yet for all of these claims, many entertain skepticism as to the reliability of sure and certain systems for acquiring knowledge and making decisions.

Knowledge, Decisions, and Extremisms

What can humans know with some measure of confident certainty, and what can we know that must always be largely contingent, exigent, and—in a word—arguable? This fundamental question engaged the ancient Greeks, as it has every civilization. There were many among the group of philosophers and teachers called the sophists who believed that knowledge must be largely, and in every field, uncertain and contingent. Susan Jarrett calls our attention to "the sophists' rejection of transcendent truths and eternal values" (2). Mark Backman argues that this way of thinking "grounds reality in the relativity of truth" (7). Certainty is an illusion, many of them argued. The sophists "acquired a reputation for a kind of intellectual disorderly conduct" in proclaiming a doctrine that "what is gained in knowledge . . . is tempered by the realization of inadequacy and impotence" (4). For the prominent sophist Protagoras, "absolute truth was unknowable and perhaps nonexistent. Man is the measure and measurer of all things" (Kennedy 13). Prominent among the sophists were those who taught the art of rhetoric, for if we cannot be sure of what to do in the choices that confront us, then we must argue among ourselves to decide prudent courses of action. Thus, Plato depicts the fifth and fourth century BCE sophist Gorgias as advertising his course of public speaking by offering in public demonstrations to speak on any topic whatsoever that anybody might pose to him.

Consider the implications of such a stance, beyond its obvious advertising value for Gorgias's school. It was clearly "a claim of omniscience" grounded in rhetorical facility (Jarrett 65). If one offers to engage in rhetoric—to give a public speech—on any topic whatsoever, one is declaring that any topic that can possibly come up is uncertain and contingent. One might ask him about moral decisions, about mathematical formulae, or matters of astronomy, and his answer would be couched in a speech. In Backman's view, Gorgias's posture was commonly shared among sophists, whose way of thinking "is shaped by the principles and techniques of persuasive communication" (6). I think we might see this willingness to treat every kind of issue as rhetorical as a kind of extremism of rhetoric. As one might imagine, this stance appalled Plato.

Plato, for his part, took the diametrically opposed stance that sure and certain knowledge is entirely and for every question possible. For Plato, "truth was absolute and knowable" (Kennedy 14). His philosophy became what we know as *idealism* (Brummett 46). One may not always "get there," but through his method of philosophical dialectic, an understanding of the dimension of ideal forms may be approached. This means, clearly, that knotty problems of moral and ethical choice, of prudent public decisions, of charting a path through the underbrush of personal issues, all these admit of the possibility of knowledge as certain as geometric or mathematical knowledge—at least in principle. For Plato, "there were sure and certain unchanging truths to be discovered about every question" (Brummett 47). If this sounds as extreme as the diametrically opposed sophists, let us at least keep in mind that a belief that sure and certain knowledge is possible has informed a great deal of popular, philosophical, and scientific inquiry to this day.

Reacting to C. P. Snow's idea of "two cultures," some of the essays in this volume address, from a different angle, the choices that the sophists and Plato seem to present to us. Those two cultures may be seen as represented by the sophists and Plato. Richard van Oort's essay here recasts Snow's distinction as a question of how one explains the origins of language. Ronald Soetaert and Kris Rutten's essay also problematizes Snow's distinction and shifts it to a discussion of narrative and rhetoric. In both essays, the question of whether answers to fundamental questions can and must be arguable or can and must be settled by sure and certain systems is relevant.

Along came Plato's student Aristotle, who must have been a great disappointment to the old professor. At the start of his celebrated treatise on *Rhetoric,* Aristotle rearranges these issues fundamentally between the sophists and Plato. He begins: "Rhetoric is the counterpart of Dialectic. Both alike are concerned with such things as come, more or less, within the general ken of all men and belong to no definite science" (19). Aristotle declares that Plato's talky method of dialectic is but the counterpart of, and no better than, the other talky method of rhetoric. Both are means of arriving at decisions about what to do in life through talking it out, either in the give and take of dialectic or the more extended exchanges of rhetoric. The counterparts, rhetoric and dialectic, are to help us in making decisions for which we have no sure and certain systems to guide us, or as George Kennedy put it, questions that "are not part of any specialized science" (19). If we face a question for which there is a sure and certain system, we should resort to that generator of reliably certain knowledge. Why argue about the area of a circle when geometry gives us a sure and certain way to that knowledge? On the other hand, why seek sure and certain systems for settling moral, ethical, and public policy issues if there are no such systems for the messy side of life?

Aristotle's distinction seems entirely reasonable, but human nature being what it is, the distinction sets up a great temptation. That is, the temptation to seek sure and certain systems for the comfort they bring, and to misapply them to questions that should instead be settled rhetorically. For sure, there are many hardy humans who do not want certainty in any question of life, who revel in the contingent, whose shibboleth is always, "it depends." I believe there are far more people in our dangerous, nervous, shifty, and contentious age who would be happy with a slogan, a formula, a word of authority to tell them what to do. Scan the self-help section of a bookstore, or an online service, and see the vast array of books offering sure and certain guides for childrearing, success in business, riches in the stock market, and what have you.

That way lies another extremism. This extremism consists not in resorting to sure and certain systems to guide decisions, but instead in resorting to sure and certain systems to guide decisions that ought to be decided rhetorically. This extremism is a poverty of rhetoric. Extremism is what happens when one eschews the responsibility to talk, to argue, to reason together, in favor of the quick and easy but illusory satisfaction of deferring responsibility to the authority of a dogma, a pontiff, a formula that is out of its league. The problem lies in knowing where the dividing line is, and in not succumbing to the extremist temptation to settle rhetorical, contingent issues with some kind of law. But remember that, as with the sophists, extremism can also be an imperialism of rhetoric, a belief that everything whatsoever can be argued about. Those who do not know when to give up arguing in the face of settled knowledge informed by sure and certain systems are extremists as well.

To define extremism in terms of rhetoric and its proper purview shows us that rhetoric is more than simply a technique or practice of communication. As Backman argued, "rhetoric is essentially an attitude about public expression and the nature of the world. It resides at the crux of the relationship between language and reality" (11). Yes, rhetoric is the ability to craft arguments and make speeches, the technique of creating advertisements and interpersonal appeals, the practice of influencing others. It is also a critical faculty, for Aristotle defined it as the ability to observe in any particular case what are the available means of persuasion—and such a definition bespeaks analytical and critical ability at least as much as the ability actually to speak and to argue (24). I am describing here a wider, more immanent, more structuring vision of rhetoric: a way of being in and thinking about the world. A rhetorical way of living is a way of accepting the contingency and uncertainty of life's choices; it keeps to a minimum those decisions for which we turn to sure and certain sciences or ways of knowing; and it approaches life as largely an adventure in choosing among uncertain choices, an adventure in making those choices with others through shared, ongoing, suasive communication.

Architectonic Systems and Their Extremisms

As a way of living and being, rhetoric is what the philosopher Richard McKeon called "architectonic": it structures other discourses and other ways of thinking. An architectonic way of thinking is a way of making decisions across the broad sweep of experience. When we speak and think rhetorically about personal relationships, politics, war, peace, finance, and so forth, we think about the means of persuasion in every case, the means of persuasively finding common ground for shared action, and the means by which we jointly and individually take responsibility for the conclusions we talk ourselves into. To think about how to give a eulogy, how to prepare a business presentation, or how to conclude a sale is rhetorical but not quite yet architectonic; we must go deeper. Underneath all, a rhetorical way of living assumes that most of those decisions are contingent and arguable, and thus eschews dogma and strident certainty as much as possible. This commitment abandons the search for foundational certainty in every question that has plagued so much philosophy over the centuries. A rhetorical way of living does not see uncertainty, doubt, and ambiguity as the fly in the ointment of epistemology, it sees epistemology as a pot of fly ointment.

Throughout history in the West, there have been a few great systems of thought that were taken to be architectonic. Of course, *any* system of thought may be so taken. One could structure the world and thought about it culinarily, or in terms of tobacco, I suppose. But the most likely systems to be architectonic are those with as little subject matter of their own as possible. A system that is widely capable of structuring but that imposes very little of its own subject—that is what makes a system architectonic.

Any architectonic system of discourse is prey to extremism, if understood as the application of a discursive system in inappropriate ways to matters for which other systems are better suited. Of course, what is appropriate or not, overreaching or not, is a matter of some dispute. But I think it is much easier to fall prey to extremism if one sends one's discursive commitment on a mission to conquer the world, than if that system is assigned a more restricted and local task.

We have discussed two such systems already: one is philosophy, to which we will turn in a moment, and the other is rhetoric of course, which has no subject matter of its own. Gorgias claimed to speak about anything at all, and he could do that because, unlike, let us say, economics, which insists on its own content area and information, rhetoric has no such content. If I were to tell you, "be rhetorical," you could not proceed. Yet, paradoxically, I can tell you "be rhetorical about X," where X is nearly any subject matter at all, and you could, like Gorgias, proceed to give an argument, a speech, a persuasive appeal about X. That does not mean that one should do so. If a rhetorical definition of extremism is to hyperextend a claim of sure and certain systems into domains that are uncertain and contingent, there is likewise a disease of rhetoric to be found in the impulse to be contentious about matters for which there are sure and certain systems to settle the matter. But for most everyday decisions, and as Aristotle noted above, for those decisions that come within the understanding and experience of most people, rhetoric can be architectonic.

Marcus Tullius Cicero's vision of the orator in his treatise by the same name imagines the ideal civic leader as one who is trained rhetorically, and who can approach any subject at all—but rhetorically (*De Oratore*). Even the knowledge made of sure and certain systems such as biology or mathematics may be subsumed architectonically by rhetoric, depending upon careful use. In the United States today, the sure and certain knowledge that childhood vaccination prevents serious diseases like measles, and is very unlikely to cause autism, evidently needs rhetorical help to persuade the recalcitrant and fretful to vaccinate their children. And so an architectonic use of rhetoric might take the sure and certain (for the moment, at least) conclusions of, in this example, medical science and still think about how those conclusions can be spread persuasively. The question of whether to build a bridge may need some sure and certain knowledge from the definite system of engineering, but the architectonic rhetorician will be thinking all the time about how to "sell" such a bridge to the public.

The second great architectonic system to which we have briefly alluded is philosophy, writ large. I realize the distinction between philosophy and rhetoric is problematic for some, and one may recall Calvin Schrag's placement of rhetoric at the "end of philosophy." Of course, there are many philosophies, and not all are in agreement, but the general method of rational argument and exchange so as to pursue some kind of truth standard, exemplified in Plato's dialectic, is surely what we might call philosophical. To be clear, to think architectonically using philosophy does not quite mean to be an idealist, a pragmatist, a phenomenologist, and so forth. Those are particular philosophical methods. To be architectonically philosophical goes to a way of living and being in the world as surely as is architectonic rhetoric: the commitment to arguing and exchanging rationally, examining premises underlying claims, and thinking about contradictions and consistencies in discursive claims, to which I alluded above. This way of living and being, of habitually thinking about the world, is what I mean here by philosophy, and by philosophy used architectonically.

As a side note, there are those who argue that the sophists were likewise philosophers, and not only rhetoricians (Jarratt). This claim is just, and I would answer it by saying that some of those called sophists were clearly what we might call philosophers (e.g., Protagoras) and some who were called sophists were clearly rhetoricians (e.g., Gorgias). For the sake of argument I am dividing the world of discourse in ways that actual thinkers and writers did not necessarily sort out into so neatly, but would plead in my defense that there are always hybrid ways of thinking, and that one might think rhetorically at times and philosophically at other times.

If I cannot reasonably tell you to "be rhetorical," then I would have not much more success in telling you to "be philosophical." I must give you a subject matter to which you might apply the methods of whatever your philosophy may be. Philosophy, also, may take the results of sure and certain systems and reason about them; if we know with some certainty that vaccinations prevent childhood diseases, then is it ethical to require that all children be so vaccinated? What are the civic and familial duties of parents in this regard? The architectonically thinking philosopher will be engaged with questions like that, making use of the sure and certain knowledge offered by medicine. Like rhetoric, philosophy may become an extremism if it attempts to decide questions for which we have *other* sure and certain systems to guide us, but it may certainly explore systems of reasoning and it may explore implications of those sure and certain systems. To be clear, philosophy, or a particular philosophy, may conclude that it does have a sure and certain system to guide knowledge, in that it reasons better or proceeds from superior premises. I am arguing that extremism occurs when that surety and certainty is extended to matters for which there are other systems with better claims to surety and certainty.

A third system of thinking and of discourse that I will now mention is also often but not always used architectonically, and that is religion, in all its varied versions. One hesitates even to bring up the term for fear of definitional tangles, but let us take a garden variety meaning of it, that religion is a system of thought meant to explain ultimate, foundational meanings grounded in transcendent, metaphysical, spiritual, and cosmic terms. We may argue over what exactly religion means, but if one were to give you a choice, "Jainism or the rules of tennis," I think there would be little genuine disagreement as to which is the religion. As with rhetoric and philosophy, religion is, broadly speaking, a way of knowing and being in the world. If phenomenology is one variation that a philosophical way of thinking and being might take, then Catholicism or Hinduism are variations that a religious way of thinking and being might take. So it may be more accurate, if we want to understand religious thinking as architectonic, to see it as a way of living and being that is fundamentally an attunement to spirit, to metaphysical dimensions of life and experience, to mystery, to transcendent structures of consciousness and influence.

Now, I have known ordinary people for whom religion is architectonic. One cannot bid these folks good morning without receiving a reply couched in religious terms, such as "a good morning to do the Lord's work." One might well argue that the great religious systems, especially as embodied in institutions, can be used architectonically and have an explanation and an answer for every issue, question, or decision one could put to them. As with rhetoric and philosophy, religion per se has no subject matter, but instead bodies forth in the subject matter of a specific religion, and even then can be applied with astonishing, and perhaps worrying, ease to any issue that might come up. You won't get very far telling someone "be religious," but if you say, "what's the Catholic take on this," the answer will be quickly forthcoming, no matter what the "this" may be.

The architectonic uses of religion can become extremist when they are applied to questions for which there are sure and certain systems that are not religious in nature. Religion has, of course, its own sureties, but when they encroach inappropriately on the better-founded sureties of other systems of thought, extremism ensues. Examples would include those who see an outbreak of measles following the reluctance of parents to vaccinate their children as God's vengeful will (when medical science has a well established pathology of measles), or who see God's hand in a storm that devastates an area they regard as particularly sinful and apostate (when meteorology has a well established model of weather patterns). As with rhetoric and philosophy, this does not mean that there can be no religious treatment of the products of sure and certain systems. Religion can see God as the transcendent foundation from which the laws of nature spring. Religion can take what we know about vaccinations and suggest what our duties are as Methodists, or Buddhists, or Rastafarians given that knowledge.

Can science be used as a fourth architectonic system? Some have done so, such as the logical positivists of the first half of the twentieth century. The question raises the issue of what science is, and if used architectonically, will it mean something deeper than the particular sciences of, for example, botany or chemistry. Like rhetoric, philosophy, and religion, architectonic science is a way of thinking and being in the world, which manifests itself in physics, astronomy, biology, and so on. What is the fundamental way of thinking architectonically through science? More complete answers to that question will be found in the other chapters in this volume, but to provide a working meaning, architectonic science is a commitment to objectivity, a commitment to methods, ideas, and conclusions that are objectively and communally examinable, the effacement of self (including emotions and biases) in deference to method and community, and perhaps most of all, a commitment to skepticism and doubt. Doubt is the specter that haunts every scientific inquiry, and levels of confidence that any given finding cannot be doubted, cannot be the result of chance, are the hallmark of science especially in regards to experiments. If a scientist declares a finding at the level of .0001, she is saying there is very little reason to doubt that the finding is random or the result of chance.

Just as all our architectonic systems have their extremisms and diseases, a surfeit of skepticism can be harmful as well. The Renaissance philosopher and rhetorician Giambattista Vico said of the skeptical scientific systems of his day,

> Philosophical criticism is the subject which we compel our youths to take up first. Now, such speculative criticism, the main purpose of which is to cleanse its fundamental truths not only of all falsity, but also of the mere suspicion of error, places upon the same plane of falsity not only false thinking, but also those secondary verities and ideas which are based on probability alone, and commands us to clear our minds of them. Such an approach is distinctly harmful, since training in common sense is essential to the education of adolescents. (*On* 13)

He argues a rhetorical training is precisely what induces common sense, an ability to make decisions in the absence of certainty. Common sense is the judicious, prudent balancing of skepticism with affirmation. And indeed, rhetoric has always studied what may be said on both sides of any issue. Vico advocates a rhetorical training that teaches, first, affirmation, and then the skepticism needed to question claims.

Complications and Cautions

Here I want to register some caveats and cautions as to what I have argued above. In the first place, I want to be clear that there are other systems of thought and discourse that may also be used architectonically, at the same time that I want to say that the four systems I have reviewed need *not* be used architectonically even if they often are. And I want to stress that although I began with a rhetorical definition of extremism, I want to claim that the discursive world is full of extremisms, which I have come around to defining as extending one's architectonic system into a realm for which the wider culture considers it inapplicable.

I also want to caution the reader that sure and certain systems change their conclusions from time to time; where once science produced phlogiston and ether, now it does not. And entire sure and certain systems themselves change. Few people think that astrology or phrenology produce such knowledge now, even if some thought so in the past. A sure and certain system is always culturally validated, cordoned off from serious doubt for a moment, treated as a settled and sedimented path to knowledge, but that cultural validation can change. Sometimes the reasons for validating or invalidating a system are ideological, as in the church's quarrel with Galileo, both claiming sure and certain systems at the same time. And surely the use of any discourse architectonically is influenced by ideology as well.

We should also briefly raise the question of how a system works architectonically if it is not verbal, for all the systems we have considered so far were at least symbolic if not verbal. This raises the obvious question as to whether art, or perhaps more accurately aesthetics, can be an architectonic system. How can we be architectonic with symbols yet not with language? Mathematics may be used architectonically; I have heard, perhaps apocryphally, of departments of mathematics whose faculty claimed they could render the Gettysburg Address into mathematical terms, which is surely architectonic. I leave it to the reader to consider whether that is an extremism. What can we say of varieties of mystic religion which claim no symbolic mediation in the direct experience of the divine? I do not intend to settle these questions, but merely to raise the issue to be taken up at another time.

Finally, a judgment of extremism in relationship to an architectonic system and *its* relationship to sure and certain systems may not be as clear in practice as in principle. Another way to put this is to say that here I have articulated some very broad and sweeping principles for which one may find many exceptions and gradations. Let me caution the reader that whatever value one finds in views of extremism must be tempered by the examination of the details of particular grounded uses of systems of discourse.

Examples

Let me note that at least two other essays in this volume explore textual examples that illustrate the principles discussed here. David J. Tietge argues that Disney nature films shift the treatment of nature from scientific to rhetorical, specifically commodified, terms. And Alan G. Gross raises questions about Steven Pinker's attempt to handle arguable issues such as history and language as if they could be addressed better through the sure and certain methods of science.

I myself want, by way of example and illustration, to examine a particular discourse that may be extremist in its moving in on what the rest of the culture might take to be sure and certain systems. I call the reader's attention to a webpage, *Vaccines: A Religious Contention,* that appears to be grounded in religion as an architectonic system that attacks the sure and certain systems of medical science, at least at this point in our cultural history. A screen copy of this page is included in the appendix. Settled medical science argues that vaccinations are important preventatives of disease and are important measures in preserving public health. The reader may be interested to note that although the burden of the page's argument is clearly religious, citing the traditions of many faiths, it concludes by claiming to be another one of our architectonic systems, namely, philosophy.

There is an interesting anonymity about this article. It appears on the Vaccine Awareness Network. If one clicks on that link from this page one comes to the home page for the network but finds out no more about who actually is speaking here. At the start of the current page under examination is a photograph of a young girl, with the caption, "Alicia playing Mary, Jesus's Mother, in a play." We don't know who Alicia is, but presumably she is the child of the author of this article. An implied frame of family and parental responsibility is thus established from the start.

By claiming the mantle of a network, and by selective citation of some comments from "members" of the public or the network, the impression is created of a community of discourse, holding similar beliefs. What will be an opposition between religious and scientific discourses is explicitly announced on this home page, with this quotation: "Qui medice vivit misere vivit—Roman saying, 'He who Lives Medically Lives Miserably.'" Once into the page that is the specific focus of examination here, it is clear that the religious is opposed to the medical and thus to the scientific.

The article opens by grounding itself in religious ways of thinking: Christian, Jewish, Buddhist, Mormon, even atheism, which after all is a system of thought oriented toward religion. The author identifies himself or herself as originally Greek Orthodox. It is in reference to these religious doctrines that the central theme of the article is introduced, which is a religious prohibition against putting into the body that which is bad for it. In contrast to the immunizations offered by medical science, the religious alternative of "spiritual immunization is offered." The very start of the article quotes one Dr. Golden who says, "To someone whose god is science, vaccination makes sense. But to someone whose god is God, it is appalling." Note that the identification of the two systems of discourse, science and religion, as capable of being taken as "god" is about as architectonic as it gets. Thus the article explicitly opposes religious and scientific ways of thinking, with clear implications that this is done at the level of the architectonic.

The author acknowledges that "there was no vaccination in biblical times," and launches into a reading of various religious texts on a theme of prohibiting putting harmful substances into the body. Note that this exercise, although it will mention other religions, is explicitly connected to the Bible from the very start, and thus, Christianity. What follows is an interesting combination of quotations from canonical scripture (Deuteronomy, Genesis) as well as apocryphal texts (Wisdom of Sirach). References that appear to be to scholarly or scientific sources, such as an article by Tim O'Shea, or a reference to the Encylopaedia Brittanica, are cited as if to subsume scientific discourse within the religious orientation of this article. Note also that at the end of the article, in discussing Islam, a Muslim author, Dr. Aisha Hamdan, with scholarly credentials is enlisted to make the statement, and she concludes thus: "We must believe in the perfection of Allah's creation and understand that immunizations are in no way able to improve upon it. Chances are that they will only disturb the system and introduce an imperfection (which is already being determined by research)." Note the reference to "research," which here is anticipated and indeed subsumed by religious thinking.

Religious thinking is used to power some big leaps of exegesis. The Book of Acts is quoted to the effect that we must obey God rather than men. But then vaccination is mentioned as a man-made substance, and not a natural function given by God. Of course, so are cherry pie, cheeseburgers, and buttermilk, but the author is picking carefully the human products she opposes. Religious belief is shown in every case to obviate medical vaccinations through the superior means of spiritual vaccination, although exactly what that might be is not made clear.

The kind of Christianity that makes the author's system of thought becomes clearer as it is set apart by sections, first from Mormonism, then Roman Catholicism, and then the Jehovah's Witnesses, before leaping the pale entirely to examine non-Christian religions. A kind of protestant, evangelical Christian system of thought is thus implied by this structure of religious discourse. The article ranges widely over other religions, and in a friendly way, but the structuring of the religions confessing Christ at the beginning reveals the author's orientation.

My claim that this article is extremist because it moves in on a terrain that is properly left to scientific discourse—that it in fact attempts to subsume scientific discourse and the appearance of that discourse onto its own religious terrain—may well be controversial. As noted above, what counts as extremism is often culturally and ideologically determined. But I think at the very least a kind of discursive imperialism may be claimed for the stance this article takes, and I would claim that is imperialist as a result of an overreaching architectonic use of religious discourse.

Conclusion

The search for an architectonic discourse is a natural human yearning. Especially in times of great change, competing loyalties, and the collapse of magisterial means for deciding among the claims of many discourses, the temptation is great to embrace a discourse architectonically. Consider this essay as a plea to take any discourse architectonically with a great deal of caution. I'm not advising one to be un- or anti-architectonic, but simply to be cautious when doing so. History has seen too many burnings, too many wars, and too much incivility engendered by certainty. Even a commitment to the uncertainties of rhetoric can become a kind of certainty, an extremism of not yielding to the settled conclusions of sure and certain systems. Picking a judicious and prudent path among discourses is difficult, and the path sometimes becomes unclear, but we live in a world where I think it is the wisest path to pursue.

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Chapter 4

Science and the Idea of Culture

Richard van Oort

Abstract

This chapter argues that the conflict between the sciences and the humanities is best understood not in terms of local cultural differences between scientists and humanists (C. P. Snow's "two cultures"), but rather in terms of the more fundamental problem of language origin. Is language an extension of animal communication systems, or is it something radically different? Is it explainable in purely Darwinian terms, or is it an evolutionary anomaly without precedent in history? The view of culture we adopt depends on how we answer this basic anthropological question.

A major theme running through all the essays in this volume is the influence of culture and society on science. Maarten Boudry and Massimo Pigliucci are merely more explicit than most when they conclude their contribution by saying that "science is social to the bone." Like all the authors in this volume, I take it as given that science exists only within the context of human beings and therefore deserves to be considered from a specifically anthropological perspective. More precisely, I think we can sharpen the debate about the cultural and social foundations of science by considering it within the context of the debate about the origin and function of culture. If culture is indispensable to science, then the success of the latter is tied to the success of the former. But what is culture and how do we explain its historical success? This is a specifically anthropological question—and it deserves a specifically anthropological answer.

It is tempting to superimpose our anthropological intuitions about culture onto our idea of science. Isn't science itself a kind of culture? After all, scientists have to interact with one another, and the concepts they use tend to be highly specific to the research communities they inhabit. Surely we can therefore speak of scientists as possessing a distinct culture, one that is not readily understood by outsiders unfamiliar with the specialized knowledge of the scientific community.

That scientists do possess a distinct and specialized culture was the view of C. P. Snow in his much discussed and now classic 1959 lecture at Cambridge University on the "Two Cultures." Snow pitted scientists against humanist intellectuals. What Snow regarded as regrettable was the mutual distrust and suspicion between the two groups. Humanists spoke one language, scientists another. Snow's sympathies were firmly with the scientists. They were the more progressive community—not in any political sense, but in the sense that history was on their side. It is often forgotten that the underlying theme of Snow's essay was not the rather toothless idea that humanists and scientists needed to start talking to one another. Rather, it was the notion that humanists had become obsolete in a world driven by science and technology. Snow's essay was an attempt to historicize and explain this situation. Of course, there was a moral point to Snow's discussion. The scientific and technological revolutions of the West had brought unprecedented prosperity to those lucky enough to be living in that part of the world that had undergone the miracle of industrialization and the subsequent consumer revolution. How could undeveloped countries catch up with their more technologically advanced counterparts so that they too could share in the wealth, comfort, and convenience of modern culture? Seen against the backdrop of this larger picture, humanist intellectuals came off as rather complacent, if not downright backward, in their attachment to a conception of culture that seemed strangely at odds with the wonders of modernization.

In this sense one must regard F. R. Leavis's attack on Snow as unsurprising. A lecturer in English at Cambridge, Leavis had remained silent in the immediate aftermath of Snow's lecture, despite the national and international attention the talk had attracted. But in 1962, on the occasion of the Richmond Lecture at Downing College, he could contain himself no longer. In a scathing riposte (later published in *The Spectator* as "The Significance of C. P. Snow: The Two Cultures?"), Leavis described Snow as "portentously ignorant" (53) and a "nonentity" (57), a man who had absolutely no talent or originality for either science or culture (Snow was a novelist as well as a scientist), but was instead a mere cipher for larger forces which he did not understand and therefore could not explain. In short, Snow was a fraud and an impostor.

Leavis's ad hominem attack was unnecessary (and indeed quite beside the point), but the notion that Snow was riding the wake of a wave he did not create and therefore could not take credit for was certainly accurate. In pointing out the superior cognitive power of science over the humanities, Snow was stating the obvious. The merit of his discussion was less in making this particular claim, which was self-evidently true, than in the minimal fuss with which the claim was presented. Unlike Leavis's assessment of the situation, there was nothing ill-tempered or defensive about Snow's recognition of the imbalance between the sciences and humanities. Of course, once this imbalance is recognized and owned up to, anxiety is inevitable. Self-doubt and self-justification set in. What is the point of the humanities? Despite their very different temperaments, both Snow and Leavis were responding to the same general anxiety about the function of the humanities in a scientific culture. Science generates no similar anxiety or hand-wringing. Its long list of achievements in producing prosperity has secured its position at the leading edge of serious cognition in society.

Next to this list of achievements, the record of humanists is much less impressive. What concepts do humanists possess that guarantee their indispensability? Snow strongly implied that there were in fact no equivalently powerful humanist concepts. This was indeed the point of Leavis's heated attack. As far as Leavis was concerned, Snow was an ignoramus who hadn't the faintest clue about what constituted genuine cultural value. The aggressiveness of Leavis's position was of a piece with his aesthetic modernism. Modernists tended to see themselves as the last guardians of high culture in a world polluted by the sentimentality and clichés of consumer culture. Hence they defined themselves in opposition to the cultural products of the marketplace. Whatever culture is, it is most definitely not that.

Here it is necessary to define the notion of culture more precisely. The concept remains rather ill-defined in Snow's essay. It is, for example, not at all clear whether it is helpful to speak of scientists as possessing a culture that can be opposed to the culture of humanists. While it is obvious that the concepts underpinning scientific knowledge are quite different from those underpinning humanist knowledge, the nature of this difference needs to be clarified.

In a book published five years after Snow's lecture, the anthropologist and philosopher Ernest Gellner took up the same topic in the context of a discussion of the wider philosophical implications of the historical transformation Snow had identified. In *Thought and Change* (1964), Gellner describes the difference between the sciences and the humanities in a characteristically stark and lucid fashion. The concepts of science, he says, are technical and difficult for a nonspecialist to understand; but they are cognitively powerful (i.e., they are demonstratively powerful in explaining nature, thus enabling us to manipulate it with increasing precision and effectiveness). The concepts of the humanities, on the other hand, are nontechnical and relatively easy to understand, but they are "cognitively feeble" (203) (i.e., humanist knowledge is powerless when it comes to explaining and manipulating the physical world). More to the point, the fundamental concepts underlying humanist knowledge are easily accessible because they concern all humanity.

This point is perhaps too easily forgotten. Humanists, in their haste to emulate scientists, have been quick to produce their own kinds of specialized knowledge. This is understandable, but the situation is not really analogous to scientific knowledge. There is nothing to be gained in cognitive or explanatory power by adding layers of technical concepts or specialized jargon to humanist knowledge. It is for this reason that Snow's idea of the two cultures is inadequate as an attempt to describe the difference between the two kinds of knowledge. What is needed is not merely a sense of science and the humanities as two different cultures, but an awareness of the anthropological origin of culture itself. Missing from Snow's discussion is the idea that culture defines not merely a community of like-minded individuals, whether they be humanists or scientists, but the role of culture in our very definition of humanity. Leavis, it must be admitted, understood this aspect of the problem better than Snow. But Leavis's conception of culture remains too bound to the high cultural tradition to provide us with a theory adequate to the task of explaining the cultural origins of humanity. Hence Leavis's rebuttal merely had the effect of accentuating the very difference Snow emphasized in his lecture.

How then are we to explain not just the differences between particular cultures but the origin of culture upon which those differences are based? Compared to other animals, humans are notoriously unconstrained by their biology when it comes to their social behavior. You can take an infant from one kind of society, say, modern industrial society, and place it in another kind of society, say, an Amazonian tribe, and it will easily acquire the cultural behavior of that particular community. Obviously, the situation can be reversed: the tribal baby could be adopted into the home of well-to-do lawyers in London. It could then make its expected passage through Eton and Oxford and become a successful barrister. There are no biological constraints on whether the baby becomes a tribal shaman or a barrister.

This kind of biological or genetic flexibility is rather unusual. It does not exist in insect societies and it exists only very minimally among social animals such as chimpanzees. For example, chimpanzees use certain kinds of rudimentary tools. They fish for termites with sticks and they crack open nuts with stones. The sticks must be slender enough and long enough to reach deep into the termite mound, and the stones must be carefully selected for their appropriateness for the task of hammering nuts. Tool use is not something that is given by the chimpanzee's biology; it is a learned behavior, and this creates the conditions for some minimal or incipient variation in behavior among individuals (i.e., some individuals will be more adept at using these tools than others). In some groups we can assume that more efficient habits of termite fishing or nut cracking will catch on, and these groups will be selected for in the Darwinian contest of survival. Surely the origin of human culture is to be found in these kinds of examples from chimpanzee life.

There is one major difficulty with this view and it concerns the appropriateness of the analogy itself. Can one really describe chimpanzee tool use as analogous to human culture? Are not the differences more striking than the similarities? For instance, why does chimpanzee culture remain obstinately stuck at the level of fishing for termites and cracking nuts with stones? What prevents chimpanzees from building on this rudimentary technology in the same way humans do? It is an obvious fact that cultural variation among humans is immense. There is a big difference between a stone chopper and a computer. Why don't we observe the same kind of variation among chimpanzees?

In his classic anthropological study of religion, *The Elementary Forms of Religious Life,* Émile Durkheim argued that the purely instrumental or positivist approach was the wrong way to go about explaining human culture. Culture is not a technology that allows humans to manipulate their environment more effectively. Rather, it is a way of constraining individual behavior by imposing on the world of everyday perception a symbolic reality that exists only relative to the group of which the individual is a participating member. This is how Durkheim defined the sacred. The sacred is what the individual is initiated into by virtue of membership in the community. Durkheim called this process "collective representation." Psychologists today call it "collective intentionality." Whatever we choose to call it, it appears to be unique to humans.

How did this collective imposition of the sacred onto the world of individual experience originate? This is a much less easy question to answer. But the question is worth asking because it allows us to see in a particularly vivid fashion the relevance of the humanities to fundamental anthropological inquiry.

The scientific answer to this question has already been given. Human culture is an amplification of the many learned behaviors observable in other social species. With sufficient time, no doubt the chimpanzees, too, will start modifying their sticks and stones into more complex technological forms and, presto, eventually they too will have cultures as variable and complex as humans. The trouble with this answer is that there is absolutely no evidence for it. Chimpanzees have been studied intensively for the last fifty years or so, but revealing though these studies have been, they have not led to the discovery of the "missing link" between humans and apes. Durkheim did not have the benefit of the ethological data available to scientists today, but his basic intuition about the anomaly of human culture when compared to animal social systems remains as relevant today as it was when he inveighed against the uncritical empiricism of Max Müller and the Victorian anthropologists. Language simply does not work in the same way that animal signal systems work. Words are not created by generalizing from one's perceptual experiences. A prelinguistic infant left to grow up alone on a desert island will not acquire language from its solitary perceptual experiences.

One of the best recent explanations of the difference between language and animal communication systems comes from the evolutionary anthropologist and neuroscientist Terrence Deacon. In *The Symbolic Species* (1997), Deacon argues that all communication systems use iconic and indexical reference strategies, but only one (language) makes use of symbolic reference. For example, in order to interpret smoke as an index of fire, one must be able to generalize from previous experiences of smoke and fire. The perception of smoke is iconic of previous experiences of smoke. The index is an abstraction from previous iconic experiences. That is, on the basis of only a limited amount of information (smoke), one infers the presence of the missing element (fire). Smoke indicates not just earlier perceptual experiences of smoke (smoke is iconic of smoke), but something which is perceptually absent (fire).

Indexical signal systems can be quite powerful. The famous case of vervet monkey alarm calls, for example, is wholly describable within the framework of indexical and iconic reference. These calls have evolved to refer to distinct categories of predator: leopard, eagle, and snake. Each call generates a distinct flight response in the monkey. Leopards can be evaded by climbing into the outer branches of a tree where the leopard is too large to follow. But this is the worst place to go if an eagle is attacking, so an eagle alarm call prompts the monkey to hide in the denser foliage at the center of the tree where eagles cannot fly. Meanwhile, the best response to the alarm call for a snake is to stand still and scour the ground to look for the offending animal (vervet monkeys do this by standing upright on their hind legs).

It is tempting to interpret these alarm calls as precursors of words because they appear to possess two key features of words: arbitrariness and displacement. There is no necessary connection between the call and its referent (arbitrariness), and the sign works independently of the presence of the predator (displacement). When researchers play a tape recording of the call, the monkeys respond with the appropriate flight pattern. As Deacon shows, however, these calls are still fundamentally indexical in structure. They have evolved over many generations to produce a highly predictable response pattern in the monkey. Deacon also shows that indexical calls can be genetically assimilated. That is, these calls are hardwired into each individual vervet brain. Juvenile vervets do not learn to produce alarm calls by imitating other vervets. In this sense vervet alarm calls are more like screams than words. If for some reason leopards, eagles, and snakes were to vanish from the habitat of vervet monkeys, the reference power of these calls would disappear because there would be no selection pressure on them. Notice that this is not the same for words, which continue to exist even when they cannot be verified. How many of us can claim to have seen or spoken to God? Despite the poverty of the stimulus, we still seem to be able to understand the word.

According to Deacon, the key to understanding the difference between a word and a vervet monkey alarm call is the way in which reference is structured in each case. What makes the alarm call "stick" to its object is the physical contiguity between sign and object. Researchers can dupe the monkey into believing that there is a leopard present in the bushes by reproducing the appropriate alarm call on a tape recorder, but this deception functions against the background of the real call which must refer to real leopards if the call is to survive over the course of multiple generations. In contrast, what keeps the reference of words in place is not a one-to-one correlation between the sign and its worldly object. It is something much more abstract. A word has meaning; it points to a general idea. But what keeps the idea in place? The idea is kept in place by the relationships among the words themselves. Words possess a grammar or syntax—a set of combinatory rules—that guide reference to the external world. Thus words possess a dual reference. They refer to objects in the real world. But the way in which they refer to the world is not via a one-to-one indexical correlation between sign and referent but by the relationships among the words themselves. This is what Deacon means by symbolic reference. Symbolic reference is the relationship among abstract symbols or tokens that in the course of human ontogeny takes increasing precedence over the more basic indexical and iconic reference strategies of our perceptual systems.

But how did this type of reference system ever get off the ground in the first place? This is a problem very few of the scientific specialists regard as a problem at all. Deacon is a rare exception. Almost alone among scientists, he sees that humanity is a radical outlier when it comes to its use of symbolic reference strategies. This presents a genuine problem for science, and for evolutionary theory in particular. In adopting such an anomalous reference system, humans are not just a super-intelligent ape but a whole new phylum. Deacon insists on this point: "It is not just the origins of our biological species that we seek to explain, but the origin of our novel form of mind. Biologically, we are just another ape. Mentally, we are a new phylum of organisms. In these two seemingly incommensurate facts lies a conundrum that must be resolved before we have an adequate explanation of what it means to be human" (*Symbolic Species* 23).

Deacon sees with great clarity the anomaly of human origin. From a strictly biological point of view, there is no anomaly. Humans originated the way all species originated, that is, through a relatively slow process of genetic change and selection. Hence the intense interest today in chimpanzees and other nonhuman primates. They represent our closest living link to our hominid ancestors. But at some point in human evolution, genetic change was superseded by cultural change. This change gave birth to a whole new category of being, namely, human consciousness. To what extent is this new consciousness describable by the sciences of biology, chemistry, and physics?

This question takes us back to the debate between Snow and Leavis concerning the use of the humanities. Despite the more up-to-date terms in which I have presented the question, the debate has not changed a great deal in its overall tone. Science continues to be progressive, which is to say, it continues to make discoveries which unlock more and more of nature's secrets. Meanwhile, the humanities continue to suffer from an inferiority complex, which tends to manifest itself in various forms of science envy and pseudoscience. Indeed, I think the inferiority complex of humanists is a great deal more pronounced today than it was when Snow first delivered his lecture on the two cultures. (For an excellent account of the invidious creep of scientism into the humanities, see Raymond Tallis's *Aping Mankind*.)

What the reference to the problem of human origin enables us to see more clearly is the limits of science when it comes to explaining human consciousness. It is in the nature of the case that human origin cannot be explained exclusively on the basis of human biology. And the reason for this is that human origin is defined by human culture, and human culture is not reducible to the genetic mechanisms of evolutionary theory. More specifically, human culture is not reducible to the genetically assimilable indexical sign systems used by all other animals, including our closest living relatives, chimpanzees. As Deacon shows, symbolic learning strategies are massively counterintuitive for chimps. It requires considerable external social support from their human trainers to get chimpanzees to set aside their indexical reference strategies in order to adopt the counterintuitive reference strategy of symbols.

These language-training experiments are highly illuminating because they show that, contrary to the Chomskian view that there must be some preexisting "language module" in the brain, the brain is actually not the key factor in the origin of language. Rather, it is the outside-the-brain context of human social organization. Early hominid ecology provided the social conditions in which it became possible to ignore the exigencies of indexical reference. This set up a feedback loop in which the ability to use symbols was selected for genetically. As Deacon nicely expresses the process of brain-language coevolution, language adapted itself to the hominid brain and the hominid brain adapted itself to language. But the crucial factor in starting the entire coevolutionary process was the internal social arrangement of the human community itself. As Eric Gans has suggested, only a species for whom the most urgent problem was internal conflict between group members rather than external competition with other species could make the shift from indexical to symbolic reference strategies (*The Scenic Imagination* 202–09). Unlike vervet alarm calls, words are not directed in the first place toward external threats. Rather, they are directed toward the group itself. As Durkheim realized, the symbols of human culture are in the first place symbols of group membership. They indicate the individual's attachment to a community of others who share the same collective view. These symbols of membership convert individual intentionality into collective intentionality, the "me" into a "we."

As an example of what I am talking about, consider the elementary gesture of ostensive pointing. It is commonly believed that pointing is a natural gesture that comes as easily to chimpanzees and dogs as it does to humans. This is not the case. Human pointing is not an index. When a dog points its nose in the direction of a duck in the reeds, its stance can be interpreted as an indexical sign of the duck. Likewise, when a chimpanzee reaches for a banana, its reach can be interpreted as an index of the banana. Laboratory chimpanzees, just like trained dogs, frequently use such gestures to indicate their desire for something. The chimp will point to the candy it wants, just as the dog will scratch at the door to indicate that it wishes to go outside. But only humans engage in pointing in order to share information for someone else's benefit. This is what we mean by pointing. When the baby reaches for its bottle, it is not pointing in this sense. Rather, it is expressing its desire, in the same manner as the dog that wishes to go outside, or the chimp that wants the candy. But when the child points to the car keys under the table, she is not expressing her desire for the keys but indicating the presence of something she believes her mother to be looking for.

The cognitive psychologist Michael Tomasello notes that this kind of pointing assumes a fairly high level of intersubjective complexity. More precisely, it requires both child and mother to engage in scenes of joint attention and joint intentionality (*Human Thinking* 32–79). The child must be able to differentiate her perspective from that of her mother. Furthermore, she must be able to adopt her mother's point of view. She must be able to put herself in her mother's shoes, and imagine what she is thinking. While trained chimpanzees frequently point to indicate that they want something, they never engage in cooperative pointing with either their trainers or other chimpanzees. For example, when a chimpanzee is faced with the task of guessing which bucket has food in it, it will not respond to the trainer who points to the bucket with the food. Instead it selects randomly. As Tomasello explains, the chimpanzee doesn't understand cooperative pointing because it does not engage in scenes of joint attention and joint intention (52). Chimpanzees have no conception of the "we" of collective intentionality. In order to see that you are trying to indicate the presence of something for my benefit, I must be able to distinguish between your perspective and mine and, what is more, that you are aware of this and wish to help me. But this is possible only if we collectively represent the food as a shared goal of our activity. Human pointing is an elementary form of symbolic reference, and therefore of language.

We are now in a position to see the inadequacy of Snow's idea of science as a self-contained culture. Culture, as Durkheim recognized, is concerned with establishing solidarity and community. Science cannot be described as having this as one of its aims. On the contrary, science is (notoriously) free of such explicit social or moral aims. Science is a method rather than a religion, philosophy, or moral worldview. The question one should therefore ask is not, "Is science a kind of culture?" but "What kind of society is capable of relaxing its cultural attachments sufficiently to allow for science?" For better or worse, this is the kind of society in which we now live. It is a pluralistic society that lacks a clearly defined common culture to which all of its members can feel a cozy moral kinship. This is one of its problems. The sense of belonging is faint, if not completely absent. But in this kind of society, science can flourish. When concepts are not graded by their proximity to the sacred or the Great Chain of Being, when they are graded by their correspondence to reality rather than their correspondence to what the chief or king or priest says, then cognition can separate itself from the sacred. But this is not the same thing as saying that science is a kind of culture. The fact that science flourishes only in a society that equalizes the relationships among concepts is, of course, enormously significant. But this equalization of concepts is not something that science itself can take credit for. Moral equalization is a product of the culture that preceded the scientific and technological revolutions in the West. Why this occurred when it did is a complex story. What concerns us here, however, are not the details of that story but the results.

As a general rule, culture is concerned with constraining individual desire. This is true of both hunter-gatherer societies and agrarian societies. Industrial or scientific society is exceptional in the sense that ethical and conceptual constraint is significantly relaxed. The cognitive ethic of agrarian society is rigidly hierarchical. Social stability is prized above all else. In contrast, industrial society is highly mobile and egalitarian. Individual identities are not rigidly tied to kinship or social status. Instead they are open and changing. This mobility reflects the opening of the cognitive and economic spheres to experimentation and choice. What is sacralized is method rather than concepts. Indeed, the sacralization of concepts takes a backseat to method. Gellner associates this liberation of cognition and production with "a rather special new and inwardly imposed restraint" (*Anthropology* 59). This new form of internal constraint is a "second-order sacralization of procedural propriety," which Gellner describes as "the rule of treating like cases alike, of conceptual tidiness, of the unification of referential concepts in an ideally unified system, and of their separation, to a remarkable extent, from the markers delimiting social conduct" (*Anthropology* 60).

The consequence of this liberation of cognition from cultural constraint is that our social rituals are no longer taken very seriously. Serious cognition today is associated with science, not with moral philosophy or theological doctrine. Yet science cannot tell us how to live. We still use the old rituals and ethical concepts, even if these no longer have the authority they once used to. As Gellner puts it, the link between serious cognition and daily life is "wobbly," because "the superior kind of truth available in science is both unstable and largely lacking in any clear social implications" (*Conditions* 94).

So we continue to use the ethical concepts inherited from our prescientific cultural traditions but in a climate where respect for these cultural concepts is not automatic. One may speak of the decline of religious culture, but this process is better described as an internalization of the sacred rather than a decline. As Snow pointed out, when disease and famine are no longer the pressing social concerns they used to be (thanks to modern science and technology), cultural constraint on desire begins to look rather quaint.

But this is not quite to concede a total victory for the sciences. When it comes to explaining culture, science will inevitably press up against its limits. For the concept of culture is meaningful only to those who also participate in it. This is the central paradox of culture. Culture depends upon biology because culture requires brains and brains are the products of biological evolution. But culture is also an institutional fact, in the sense described by John Searle. Searle distinguishes between the "brute" facts of physics, chemistry, and biology and the "institutional" facts of our social systems. Institutional facts occur when a social function is imposed on a brute fact. Searle's favorite example is money, but the key evolutionary step occurs with the origin of collective intentionality: "the truly radical break with other forms of life comes when humans, through collective intentionality, impose functions on phenomena where the function cannot be achieved solely in virtue of physics and chemistry but requires continued human cooperation in the specific forms of recognition, acceptance, and acknowledgment of a new *status* to which a *function* is assigned" (*Construction* 40).

As Searle makes clear, institutional facts require language. An increasing number of scientists are beginning to realize this fact about human culture. "It is simply not possible," Deacon writes, "to understand human anatomy, human neurobiology, or human psychology without recognizing that they have all been shaped by something that could best be described as an idea: the idea of symbolic reference. Though symbolic thinking can be entirely personal and private, symbolic reference is intrinsically social. Not only do we individually gain access to this powerful mode of representation through interactions with other members of the society in which we are born, but symbols themselves can be traced to a social origin" (409–10).

Snow criticized humanists for failing to take an interest in the work of their colleagues in the sciences. For the reasons Gellner states, genuine dialogue between humanists and scientists is rare. But there is one area in which dialogue seems both desirable and necessary. The problem of human origin concerns both parties alike. The sooner humanists recognize their stake in this fundamental question, the sooner they will be able to overcome their anxiety about the function of the humanities in a culture that privileges science as the only form of serious cognition.

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Chapter 5

A Rhetorical Analysis of the Two Cultures in Literary Fiction

Ronald Soetaert and Kris Rutten

Abstract

This chapter reconstructs the debate between and about the "two cultures" from a rhetorical perspective. Science and literature are described as particular terministic screens, and the binary oppositions between these different "ways of seeing" are problematized. The major focus is on the importance of rhetoric and narrative in general and the role and function of the humanities—literary culture—in particular. Two novels (*Saturday* and *The Children Act*) are analyzed as a case study to reflect upon how the novelist Ian McEwan problematizes and thematizes the confrontation between art and science.

The Two Cultures

In this chapter we focus on the "two cultures" coined by C. P. Snow in 1959 to describe the gap between literary intellectuals and scientists. In its afterlife, the concept survived as a trope framing the debate between the humanities and science. We—the authors—belong to the first tribe (the humanities) and in our research and teaching we argue for the importance of narrative and rhetoric. In what follows, we thematize and problematize specific binary oppositions in general and we analyze two novels of Ian McEwan in particular as a case study to reflect upon how a modern novelist deals with the ongoing debate between the two cultures.

As a scientist and literary author, Snow knew both academic tribes and could testify—as a kind of anthropologist—about the divide between them. Snow argues that the “members” rarely encounter each other in a fruitful dialogue or conversation. He warns that this indifference between the two cultures could become an obstacle for dealing with society’s major problems. Rhetorically, Snow addresses his colleagues from literary departments and makes them responsible for this absence of dialogue. An often quoted passage from the essay summarizes the major problem the author puts on the agenda: “A good many times I have been present at gatherings of people who, by the standards of the traditional culture, are thought highly educated and who have with considerable gusto been expressing their incredulity of scientists. Once or twice I have been provoked and have asked the company how many of them could describe the Second Law of Thermodynamics. The response was cold: it was also negative. Yet I was asking something which is the scientific equivalent of: Have you read a work of Shakespeare’s?” (*The Two Cultures* 14–15).

From a rhetorical perspective, Snow creates a scapegoat: the traditional humanistic literary scholar who lacks informed knowledge and so becomes out of tune in a world that has changed and is changing driven by major revolutions inspired by science and technology. It is difficult to deny—even for the hard-boiled humanist—that scientific and technological revolutions have changed society and have brought prosperity and comfort for those who can benefit from them. Probably traditional humanists can feel offended by two major suggestions: their lack of knowledge about science and the superiority of scientific knowledge. Although the debate of the two cultures can be described as a confrontation between science and the humanities, Snow mainly focuses on a gap between scientists and literary intellectuals. And indeed, the debate was further framed this way by the reaction of Cambridge literature professor F. R. Leavis, who attacked Snow with a number of ad hominem arguments: Snow was “portentously ignorant” about culture in general, “intellectually as undistinguished as it is possible to be” (54), and as a novelist, “[could not] be said to know what a novel is” (53–54). Leavis defends the major value of the humanities inspired by the attack—which he takes personally—from Snow. But there is more: Leavis was deeply concerned about Snow’s ideas about education in general and his utilitarian perspectives on economic development in particular (see Hughson and Tapsel for a discussion about the rhetoric of Leavis; see also van Oort in this volume).

In hindsight, Leavis makes a critical point that today is still high on the educational and political agenda: an economic logic based on technological development can hardly be considered the only mission for education. For example, Gert Biesta recently argued for the importance of value judgments "that are not informed by instrumental values but by what we might best call *ultimate* values"—a Burkean adjective—in this case, "values about the aims and purposes of education" (35–36; see also Jennifer Richards). The arguments of Leavis echo a concern we have to deal with today: science and technology should be confronted with social, political, and cultural values to avoid an overoptimistic technocratic naivety. So, the argumentation goes further and deeper, and becomes more relevant than the personal attack of Leavis on Snow.

The debate about the two cultures reappeared on the agenda in what has been coined "the science wars." This controversy started in the 1990s with an attack on postmodern and poststructural thinking, and constructionism in general. It is a debate that also focuses on the nature of scientific research and theory and the status of the scientific method based on objectivity. It is very difficult to summarize this controversy in a fair way because both participants very often complain that the other did not understand or present their position in a correct way. The trope "the science war" can make us wonder about who started the war. From the perspective of science, it could be argued that the war began from the moment that scientific research was described as a series of changing paradigms (Thomas Kuhn). All this (and much more of course) inspired postmodern thinking that focused on the idea that scientific theories were social constructs (again problematizing objective scientific knowledge) on a complex continuum with some midway views. The attack focuses on postmodern anti-intellectualism and relativism as a "flight from reason" (Gross et al.). The science wars, then, can be described as a kind of revival of the two cultures controversy.

Third Culture

It seems difficult to avoid binary thinking in this debate. But how do we deal with binaries? Even Snow (*The Two Cultures* 9) was aware of the drawbacks of binary thinking, because the number two "is a very dangerous number: that is why the dialectic is a dangerous process. Attempts to divide anything into two ought to be regarded with much suspicion." And he further elaborates: "The clashing point of two subjects, two disciplines, two cultures—of two galaxies, so far as that goes—ought to produce creative chances. In the history of mental activity that has been where some of the breakthroughs came. The chances are there now. But they are there, as it were, in a vacuum, because those in the two cultures can't talk to each other. It is bizarre how very little of twentieth-century science has been assimilated into twentieth-century art" (*The Two Cultures* 16). Later in *The Two Cultures and a Second Look,* Snow suggests the importance of a possible mediating "third culture," a zone in which the humanities and science would communicate in equal dialogue. John Brockman took this statement from Snow pleading for "the third culture thinker" as the new public intellectual: "a synthesizer, a publicist, a communicator" (Brockman *The Third Culture* 19). From this perspective, scientists communicate directly to the general public. The project is also inspired by how science and technology affect our culture by posing a central problem: "What we've lacked is an intellectual culture able to transform its own premises as fast as our technologies are transforming us" (Brockman, qtd. in Leggiere).

This idea was the basis for Brockman's project, Edge, the Third Culture, with major scientists who published under this umbrella: evolutionary biologists such as Stephen Gould and Richard Dawkins, mathematicians such as Marvin Minski and Roger Penrose, physicists such as Paul Davies, philosopher Daniel Dennett, and novelists such as Ian McEwan. All are committed Darwinians inspired by perspectives of evolutionary biology and Darwin's natural selection. From the same Darwinian perspective, literary criticism coined "evolutionary literary criticism," inspired by the idea of looking for an evolutionary explanation of literature (with E. O. Wilson as a major influence and Joseph Caroll as a major promoter). Again, a Darwinian perspective is a major inspiration combined with strong criticism against constructionist, poststructuralist accounts of scientific discourse as linguistically determined (see, for example, the Sokal Hoax as a major attack).

Last but not least, we should mention the perspective of New Humanism, a movement made famous by Richard Dawkins (*The God Delusion*), mainly argued for by attacking beliefs in God and advocating rationalism (see for example the *British Humanist Association* website). And we should add New Atheism as a similar contemporary movement in which "new" refers to more publicly oriented publications focusing on an aggressive stance against all beliefs in God as erroneous and even dangerous for society. Central here is the dichotomy between religion and science. And we could add more perspectives to problematize the binary model. As Stephen Jay Gould writes, all these extensions of perspectives lead to "the death of the dichotomous model that had sparked all the controversy in the first place! Thus, I view the history of discussion about Snow's 'Two Cultures' as a lesson in the fallacies and dangers of dichotomy (while I obviously do not deny the value of such simplification in provoking discussion and better resolution)" (94).

Indeed, we can wonder what the validity is of all these binaries and how they create caricatures of a debate that is more complex. Even Snow became aware of the danger and he "explored the middle ground between these artificial end points" (Gould 94). Gould pleads for a more nuanced perspective by paying attention to "a vast mass of scholars, probably constituting the great majority in a continuum that certainly cannot be defined by the rare extremes of each terminus" (94).

Binaries

We structure the world through language in binaries, and whenever there is such a polar opposition, one of the two assumes a role of dominance—overtly or covertly—over the other (deconstruction can be described as a critical reflection about this process). So even if we try to overturn the traditional opposition (for example a scientific perspective is superior to a humanistic perspective or a humanistic perspective overrules scientific perspectives), then this "just means that the underdog is defined as overdog, and we are still left with thinking in terms of dominance or hierarchy" (Elbow 51). Peter Elbow argues that the question is "not whether to deal with dichotomies but how to deal with them," and he suggests five options: "(1) choose one side as right or better. This is 'either/or' thinking; (2) work out a compromise or a dialectical synthesis, that is, find a third term; (3) deny there is any conflict; (4) affirm both sides of the dichotomy as equally true, necessary, important, or correct; and (5) reframe the conflict so there are more than two sides" (54).

Elbow analyzes the different options and describes the first three as the most habitual way to deal with binaries, but he prefers the last two as more interesting perspectives. And he further argues, against any possible reproach, that he is "saving binary thinking." We concur with his argument: "Just so long as there's more than one! If we can see three or five sides, that's good—so long as that multiplicity isn't a cover for letting one side be the real winner." His real goal is "not to have pairs but to get away from simple, single truth—to have situations of balance, irresolution, nonclosure, nonconsensus, nonwinning" (Elbow 51). And we could not agree more with the kind of perspective that evolves from such an attitude, that is, "affirming both sides of a dichotomy as equally true or important, even if they are contradictory" (Elbow 51).

We should be careful here and Elbow certainly is; he does not go so far to say it is possible or necessary to balance every dichotomy: "it sometimes makes sense to choose one side as right, the other wrong." There are indeed good and bad dichotomies: "I'm just pleading for more effort to notice the many situations where the easy, good/bad distinction gets us in trouble and we need balance and irresolution" (54). The same perspective could be true for a constructionist perspective. In *The Social Construction of What,* Ian Hacking describes the constructionist perspective as a "primer for noncombatants" in the war by focusing on the different senses of the word "construction," and indeed the book helps "the anti-constructionists get clearer on the actual contours of their enemy's position" (Andrew Pickering qtd. in "*The Social Construction*"). Hereby Hacking defends the importance of such a perspective but also criticizes the aggrandization of the concept in the transformation of the construction of "everything." Paul Boghossian describes this perspective as follows: "As Hacking rightly emphasizes, however, it is one thing to say that true and false beliefs should be treated symmetrically and quite another to say that justified and unjustified ones should be so treated. While it may be plausible to ignore the truth or falsity of what I believe in explaining why I came to believe it, it is not plausible to ignore whether I had any evidence for believing it" (7). Probably the main argument is that through the lens of social constructionism we focus not only on worldly aspects—facts—but on our beliefs of them.

In *Cosmopolis: The Hidden Agenda of Modernity,* Stephen Toulmin situates the two cultures debate in a historical evolution by making a distinction between the two cultures as they originated in the fifteenth and sixteenth centuries. Richard Rorty synthesized the view of Toulmin as a way of defending the humanistic literary tradition: "By showing how different the last three centuries would have been if Montaigne, rather than Descartes, had been taken as a starting point, Toulmin helps destroy the illusion that the Cartesian quest for certainty is intrinsic to the nature of science or philosophy" (qtd. in "*Cosmopolis*"). Toulmin argues for a tolerant perspective: "We are not compelled to choose between 16th-century humanism and 17th-century exact science: rather, we need to hang on to the positive achievements of them both" (71). The task, therefore, is neither to reject modernity nor to cling to it in its historic form: it is "rather, to reform, and even reclaim, our inherited modernity, by humanizing it" (71). As part of this humanizing perspective, Toulmin adds: "Since the mid-1960s, rhetoric has begun to regain its respectability as a topic of literary and linguistic analysis, and it now shares with narrative an attention for which they both waited a long time" (187). In the next part, we focus on the importance of rhetoric and narrative for our discussion in general and for the role and function of the humanities in particular.

Rhetoric/Narrative

In what follows, we introduce rhetoric as part of a broader perspective that can be summarized as a rhetorical and narrative turn in the humanities and the social sciences. The "rhetorical turn" is inspired by the idea that we all have become a kind of *homo rhetoricus,* since we have become self-conscious about how language constructs reality (on this, see also Brummett in this volume). Such a perspective implies a metaperspective synthesized by Kenneth Burke as "a way of seeing is also a way of not seeing" (*Language* 49). Rhetoric makes us aware that ways of seeing the world can be considered as rationalizations. Burke described human beings as symbol using and misusing animals, and so he describes human action in symbolic terms in general with a central focus on the importance of language and culture in particular. For Burke, human beings experience their generic animality in terms of a specific symbolicity (*A Grammar*).

Inspired by Burke, Clifford Geertz described the human being as "an animal suspended in webs of significance he himself has spun," and he takes "culture to be those webs, and the analysis of it to be therefore not an experimental science in search of law but an interpretive one in search of meaning." From this perspective, culture is described with the metaphor of a "text" ("the culture of a people is an ensemble of texts") (452). In *Living and Learning as Semiotic Engagement,* Andrew Stables suggests that this perspective opens new approaches to knowledge: "if the world is a text, then literary studies may be the way to understand it" (2). In his introduction to Stables's book, Richard Smith problematizes the fact that the hard sciences have become our primary model of knowledge and understanding and wonders "what a difference it would make if this model, were, say, literary criticism" (i). This perspective suggests a "reading" of the world in the same way that "a good reading of a poem, novel or film is . . . one that opens up further discussion, offering new insights to be debated or even new concepts in which to conduct the debate" (ii) (see also Rutten and Soetaert, "Signs and Symbols"). From the same perspective, Richard van Oort (2004) argues, "the human is a text to be interpreted, not because there is 'nothing outside the text' but because without the text there is no humanity. To the biologist or physicist (as for any natural scientist), it is certainly absurd to claim there is nothing outside the text. But to those concerned centrally with the study of the human (that is, those in the humanities and the 'anthropological' social sciences), it is literally quite true that without the mediating presence of the originary scene of symbolic representation—'textuality,' if one likes—there is no humanity and therefore no object of study" (638–39). (For an extended discussion on this see Rutten and Soetaert, "Signs and Symbols.")

From this perspective, the rhetorical turn can be linked with the narrative turn. Burke's study of rhetoric starts from an analysis of literature and drama as tools to comment on society and the nature of human symbol use in general (on this, see also Tietge in this issue). Burke described literature as "all medicine" and "equipment for living": "sizing up situations in various ways and keeping up with correspondingly various attitudes" (*Philosophy* 304). He compares the analysis of literature as a form of sociological criticism and so relates the metaphor of equipment to an ethical turn in literary theory, criticism, and education. The role of criticism and education—all kinds of reflection—can be summarized in another motto: we have to become symbol-wise (Enoch). But as symbol-using animals we should add we are all story-telling animals (MacIntyre). Walter Fisher introduced an extension of Burke's description of human beings by suggesting the narrative paradigm as an alternative to the rational paradigm. The metaphor "homo narrans" has become a master metaphor suggesting that human beings tell stories to describe, interpret, and evaluate the world they inhabit. As far as the narrative turn is concerned, we should mention the work of Jerome Bruner as one of the founding fathers defending the importance of narratives as a mode of knowing. Bruner confronted two complementary modes of knowing of indeed two cultures: the "logico-scientific mode" and the "narrative mode" (Bruner x). The logico-scientific mode focuses on general and empirically tested truths. The narrative mode looks for the motives of human actions (what and why?) and the context in which these actions took place (where and when?) (see also Rutten and Soetaert, "Narrative and Rhetorical Approaches").

Ian McEwan

In what follows, we will introduce Ian McEwan's work as a case study—or as equipment—to explore the confrontation between different perspectives "on" and "in" the two cultures. First, we want to situate the position of McEwan in the debate about the two cultures that we reconstructed above. We argue that he participates explicitly and implicitly in this ongoing debate. As a public intellectual and essayist he echoes some of the critical and even sneering arguments of Snow against the literary intellectuals. McEwan seems to identify more with scientists than with his literary colleagues. As a novelist he is presented and presents himself as a fellow traveler with the Edge authors, and publishes on their website (see, e.g., "On Being Original in Science in Art") and he is introduced in the anthology as one of the usual suspects (see his introduction in Brockman). McEwan also publishes under the umbrella of evolutionary literary criticism (e.g., his chapter in Gotschall and Wilson's classic, *The Literary Animal*). McEwan also takes part—as a public intellectual—in the recent revival of humanism. He is announced on the website of the British Humanist Association as "Writer and distinguished supporter of Humanism." In the periodical, *The Humanist,* his novel was recently announced as follows: "Humanists sit up and take notice—*The Children Act* is a cautionary tale for those of us who would encourage people doubting their faith to explore those doubts" (Kalmanson).

McEwan is also linked with the New Atheist movement in general (see, e.g., Dawkins's seminal work, *The God Delusion*) and *The New Atheist Novel* in particular (Bradley and Tate). McEwan describes 9/11 as a ground-breaking moment in his thinking about religion: "When those planes hit those buildings and thousands of innocent people died and tens, twenties, hundreds of thousands of people started to grieve, I felt, more than ever, confirmed in my unbelief. What God, what loving God, could possibly allow this to happen?" (Whitney). A momentum McEwan compares with how the death of his favorite daughter deeply changed Charles Darwin. He further argues that the secular spirit (inspired by science) is superior for making reasonable judgments and defends atheism and the secular state against religious "attacks." So McEwan belongs to the "Third Culture Club" of scientists, linguists, and philosopher-scientists but still plays his role as a novelist. This creates a paradox because he is at the same time a novelist, writing fiction (belonging to the humanities), and a defender of the superiority and importance of science. It is not in the scope of this chapter, but in his later novels scientific issues play an important role, for example, science and superstition (*Enduring Love*), the new physics (*The Child in Time*), and ecological problems (*Solar*). About *Solar,* McEwan reflects on how we should talk about the state we have got ourselves into, "as a very successful, fossil-fuel-burning civilization?" (qtd. in Detmers et al. 210). The question how we can change ourselves is described as a matter of human nature and then literature appears as a tool for reflection: "There's all the science to consider, but finally there is a massive issue of politics and ethics" (Tonkin *I Hang On*).

As we already argued, McEwan's work can be linked with the debate about the two cultures, but Snow published his ideas in the genre of the essay, and although McEwan also wrote essayistic reflections, his main work consists of novels. Although these fictional works have essayistic characteristics, he belongs to the category of those authors who "accommodate facts and arguments into a prose that resists being candidly discursive" (Robson). At the same time, he problematizes and thematizes the role of narratives in general and literature in particular. Very often, themes that are central in constructionism and postmodernism play a central role, for example, Joe Rose in *Enduring Love* elaborates on the axiom that "there can be no thought without language" and even implicitly refers to the Snow debate: "Did the scientific illiterates who ran this place and who dared to call themselves educated people, really believe that literature was the greatest intellectual achievement of our civilization?" (*Enduring Love* 45–46). The power of stories is problematized: "What I liked here was how the power and attractions of narrative had clouded judgment" (*Enduring Love* 41) (see also Amigoni; Carbonell).

McEwan thematizes and problematizes literature in his work. He remains fascinated by the question: what is the role of art in general and the humanities in particular? McEwan testifies: "I hold to the view that novelists can go to places that might be parallel to a scientific investigation, and can never really be replaced by it: the investigation into our natures; our condition; what we're like in specific circumstances" (qtd. in "Ian McEwan"). The idea that novelists have their own place to participate in the debate about the two cultures inspired Amigoni in arguing, "The crucial point about humans is that they are necessarily in two places at the same time—the order of nature, and the fields of inherited social practice and culture, and much of the most exciting work currently is concerned to break down the conceptual divide between the two . . . Even so, the orders and branching of biogenetic evolution and cultural-linguistic evolution will continue to work in different ways" (Amigoni 166). In what follows we will elaborate on how "cultural-linguistic" research is done by McEwan, focusing on the importance of narrative and rhetoric. We concur with Amigoni who further writes, "If the Third Culture contends that culture is now science, then McEwan's fiction subtly and respectfully contests this view by seeming to suggest that it is necessary to be in two places at the same time—literature and science—when reflecting on where, as a species, our narratives are taking us" (166).

In the next part, we will focus on two novels—*Saturday* and *The Children Act* as case studies. In *Saturday* McEwan immerses himself in brain surgery, whereas in *The Children Act* he focuses on the rhetoric of the law. In an interview (McCrum) McEwan testified, "I love professions," and, "I've always liked research, and I love people's expertise." McEwan describes the training and the occupation (the terministic screens) of his characters in a narrative form as a trained incapacity or an occupational psychosis. Burke (*Language* 45) introduced the concept "terministic screen" to describe the way we select symbols—a discourse—to frame reality. Particular screens create a particular way of seeing, thinking, and acting. Terministic screens can also be described as a "trained incapacity"—another central concept from Burke in which he focuses on how language and stories allow us to think and to act in a particular way, but also prevent us from choosing alternative ways. A similar concept is "occupational psychosis," described as "a certain way of thinking that went with a certain way of living" (*Permanence* 240). Later in this chapter, we will illustrate how McEwan confronts different terministic screens, inspired by a particular training or psychosis.

Saturday

Saturday is narrated by Henry Perowne, a neurologist, and follows one dramatic day in his life. In the background there is a political confrontation, foregrounded in debates with his daughter inspired by the world after 9/11. Because of the perspective of our chapter we focus on the conflict between the two cultures on different levels in the story. First, the family level, which is presented through the worldview (terministic screen) of Perowne and the confrontation with his children. Perowne espouses scientific positivism as an essential aspect of his profession as a neurosurgeon: "A man who attempts to ease the miseries of failing minds by repairing brains is bound to respect the material world" (*Saturday* 67). But Perowne is also a man of two cultures. In his family, artistic types surround him and he wants to learn from them or at least understand what drives them. As a father and family man he listens to the jazz band of his son, reads the book list suggested by his daughter, and also wonders what drives his father-in-law John Grammaticus (what's in a name?), a poet, or anyway a kind of literary bohemian. The characters appear as pawns in a game, in an ongoing debate between the two cultures: science and art.

The daughter plays a major part in the story and can be interpreted as an antagonistic character representing the perspective of the humanities in general and literary culture in particular. She more or less educates the father (or humanizes him, one could argue) by presenting him with a reading list because he lacks "imagination," which makes him a "coarse, unredeemable materialist" (*Saturday* 134). Perowne is doubtful about what literature can mean for him, compared with his daughter who believes in the saving powers of literature. Are we story-telling animals? McEwan seems to argue that some of us are not, and Perowne is presented as the "living proof" that people can live without stories (*Saturday* 68). The discussion is presented through a dialogue between father and daughter. Perowne asks her not to suggest novels with a magic realistic touch anymore: "Please, no more ghosts, angels, satans or metamorphoses. When anything can happen, nothing much matters. It's all kitsch to me." And the daughter answers: "You ninny," she reproved him on a postcard, "you Gradgrind. It's literature, not physics" (*Saturday* 66–67). So Perowne does not just read the novels but he also is a reluctant, critical reader who problematizes "his" literary education, complaining that his daughter Daisy's "reading lists have persuaded him that fiction is too humanly flawed, too sprawling and hit-and-miss to inspire uncomplicated wonder at the magnificence of human ingenuity, of the impossible dazzlingly achieved" (*Saturday* 67). On the other hand, it is through a novel that these questions about novels are posed. Apart from problematizing the function of reading literature, McEwan thematizes postmodern literary cultural perspectives and attitudes. The father also educates the daughter (or the scientist educates the literary humanities).

McEwan uses his story to educate the reader about the science wars and argues against particular aspects of the humanities in general and postmodernism in particular. McEwan/Perowne refers to a debate with his daughter about postmodern, constructivist perspectives on what he considers his own field or scene: madness as a social construct (echoing ideas from postmodernism in general and probably Foucault in particular, but also focusing on the teaching of literature at university level): "In her second year at Oxford, dazzled by some handsome fool of a teacher, Daisy tried to convince her father that madness was a social construct, a wheeze by means of which the rich—he may have got this wrong—squeezed the poor. Father and daughter engaged in one of their energetic arguments which ended with Henry, in a rhetorical coup, offering her a tour of a closed psychiatric wing. Resolutely, she accepted, and then the matter was forgotten" (*Saturday* 92). So McEwan—through a confrontation between his characters, father and daughter—rhetorically wins the argument between realism and constructionism, between science and (some extreme aspects of) postmodernism.

Probably another example of the superiority of science could be the fact that Perowne recognizes the neurological conditions of a dangerous man, Baxter, who attacks him in the street. As a brain specialist, he notices Baxter's odd movements and diagnoses these as the effects of Huntington's disease: "Your father had it. Now you've got it too." (*Saturday* 95). Perowne explains that there are new medications for curing this disease, and he can escape, thanks to this deus ex machina. And the same perspective is more or less repeated in the book's final chapter: again the doctor tries to convince Baxter of the state of his illness and the fact that he can be cured. But he uses this knowledge to eliminate his attacker. Later, he wonders if he has broken the moral code as a doctor, sinned against the Hippocratic oath. But in the last episode, we can see how he follows his Hippocratic oath when he drives to the hospital to perform emergency surgery on the man who assaulted him and his family and even tried to rape his daughter.

The last scene also contains an ultimate reflection on the function of art. The attacker has entered the house of the Perownes and threatens to rape the daughter. The tension is created in a stereotypical scene: a dangerous mentally deranged man with a knife against a nice, vulnerably naked woman. And then a deus ex machina is introduced to save the situation. The daughter recites a Victorian poem, Matthew Arnold's "Dover Beach," and this creates a miraculous transformation in the character of the attacker. He is so moved by the poem that he leaves his victim alone: "It's beautiful. You know that, don't you. It's beautiful." Can such a scene be read as the proof of the importance of poetry? As an illustration of the liberating and humanizing qualities of literature? Can literature be described as a way to stimulate empathy even for a mind as deranged as Baxter's? Can we believe this denouement? Can we believe in the civilizing effect of literature on the brain level? As a reader, you cannot help thinking about Perowne's own words: "It's all kitsch to me." In fact, such a story is exactly what Perowne despises in literary fiction. And yet the transformation of Baxter teaches Perowne (and of course the reader too) about this other perspective on life or this other literacy.

It is probably not just a coincidence that McEwan has chosen a poem by Matthew Arnold. On the level of the story, it teaches us something about cultural literacy. Baxter, an uneducated thug, thinks the poem has been written by the daughter and even Perowne—who as her father has read all her poems—is not aware it is not a poem of his daughter's and is affected by the words. What point is McEwan trying to make? "Is he commenting on literature's life-changing abilities? Is the novel's denouement—Baxter's under Perowne's knife—meant to indicate that the sciences have the same life-changing capacity as poetry?" (Fang). That kind of question focuses on the function of literature in general but also on the possible function of literature as "medicine." The importance of a literary education as part of medical training (or any other profession) is high on the educational agenda today. In previous works McEwan has focused on this question. For example, in *Atonement* a similar case was presented through the character of Robbie Turner, who started studying English literature but changed his mind and decided to study medicine. This binary opposition is transformed into a fruitful dialogue: "For this was the point, surely: he would be a better doctor for having read literature. What deep readings his modified sensibility might make of human suffering, of the self-destructive folly or sheer bad luck that drive men towards ill health! Birth, death and frailty in between. Rise and fall—this was the doctor's business, and it was literature's too" (*Atonement* 93).

If literature is described as equipment—or as a possible medicine, we can wonder what kind of evidence-based research will back up this hypothesis from a more scientific, empirical perspective. McEwan shows the complexity. As Jane Mcnaughton argues: "*Saturday* does not make a convincing case for the efficacy of a literary education for doctors." Indeed, "Perowne can live without fiction and is clearly able to be responsive to his patients' stories without first having his sensibilities refined by literature" (qtd. in Fischer 108). Fischer further comments, "Ian McEwan's *Saturday* is a particularly rewarding novel for discussions within the medical humanities—not because it provides answers about the relative value of literature and medicine or any concrete advice for doctors, but because it illustrates the interface between these worlds, the novel also highlights the radical differences between them. Most remarkably, *Saturday* contains an implicit critique of ingenuous readings that disregard the specificity of literary communication" (108). But the importance of *Saturday* is that the novel "provides a meditation on how we might further bridge the gap between the humanities and the sciences of mind through cautious collaborations based on the biological rootedness of storytelling, the centrality of feeling to thinking, and a shared empiricism that embraces human activities of interpretation balanced by testing, calibration, and revision" (Thrailkill 171). Anyway, Perowne tells a story doubting the importance of storytelling. He does a rhetorical reading of the perspectives of others, he tries to understand their ways of seeing, problematizes the binaries, and learns the rhetorical lesson as expressed by Burke: "a way of seeing is a way of not seeing" (*Language* 49). The novel can thus be read as equipment for living.

The Children Act

The second novel we discuss, *The Children Act,* can be described as "in a sense a companion piece to *Saturday*" (Gardner) because the novel again focuses on a profession and the relation between the two (and even more) cultures: science (again represented by medicine), art, and religion (confronted with the secular law). Apart from the thematic parallels, the main characters live in the same class or social world and in both stories medicine plays a role (both cases of medical emergency). The novel tells the story of Fiona Maye, who is trained as a lawyer and works as a high court judge dealing with cases in the family court. The story opens with the crisis in her (childless) marriage because her husband argues that he—in his early sixties—is entitled to enjoy a more passionate affair with a younger woman (his 28-year-old statistician). The novel can also be read from the perspective of terministic screens, law and art, which dominate her life, or as an occupational psychosis or trained incapacity which inspires her actions. The real plot starts with the fact that Fiona has to deal with an urgent case and has to make a decision whether a young boy (a few months shy of his eighteenth birthday) with leukemia should be forced to undergo a blood transfusion that is necessary to save his life but which his religion, Jehovah's Witness, prohibits. Should the secular court overrule the faith of the family and the boy? The doctors feel they cannot follow the religious arguments because it is against their Hippocratic Oath (an echo from *Saturday*). But the judge has to decide. We are between a religious and a scientific or secular (medical) perspective. So McEwan adds a third player in the two cultures debate: religion. But the novel also deals with humanism in general and with an aspect of traditional humanism: the importance of kindness.

Fiona appears to be kind, decent (in her work) and faithful (in her marriage), but this combination seems problematic: she cares too much for others and in the long run this is "imperiling her marriage" and "preventing her ever getting round to having children of her own" (Leith). She is described as if she belongs to the law "as some women had once been brides of Christ" (McEwan, *The Children Act* 45). She represents the secular Western Enlightenment, the "good Englishman" as portrayed in Dickens' Bleak House: "John Jarndyce of Bleak House, the soul of kindness" (Wilentz).

The words "kind" and "reasonable" are buzzwords throughout the novel. Yet, as McEwan illustrates, both concepts are complicated. Complicated when confronted with religion: Orthodox Jews or Catholics make decisions for their children so as not to interfere with God's purpose. Complicated because arguing with the family seems complex: the reasonable arguments of Fiona do not change the opinions of the boy and his family; they even make them stronger. Complicated also because indeed, "the problem is that kindness is voluntary, unwarranted by law" (Wood), and how far does engagement reach? We do not want to spoil the plot, but although she does help the boy on a professional level, at a certain moment she fails him — a poet, a musician — on a personal level. Intervening seems complex. Although the novel focuses on the particular law case in which Fiona is involved, it leads to a much wider political question. How far can we go in intervening? Is it right to "intervene" to save a life?

The novel can be read as "a kind of fable about Faith versus Science and the State" (Friedell), but is more than "a feelgood fable of secular enlightenment" (Tonkin "The Children"). The story does not give solutions, but thematizes and problematizes major issues. As we have discussed, a major topic is the binary between science and religion. But there is more: the whole story is also embedded in the debate between religion versus humanism, and in a sense about the confrontation of the humanities and art in particular. Apart from the controversy between science and religion, art plays a central role in the novel in the lives of the main characters. As in *Saturday,* poetry plays a role in *The Children Act,* more precisely, Yeats's "Down By the Salley Gardens" creates a bridge between the lawyer and the boy. Moreover, the boy appears to be a gifted poet and Fiona appreciates his romantic poetry.

Music again plays a central role in the story. The focus is on classical music and especially on a concert as a major event in Fiona's life, in which she plays with her lawyer colleagues. The scene in which she performs Schubert successfully tells us something about the function of art: she forgets about her duties as a judge because she is absorbed by the music and her responsibilities towards her fellow musicians, the audience, and the composer. Her mind is filled with Mahler and Schubert. McEwan confronts the two cultures (law and music) in Fiona. She gives an excellent performance but hardly enjoys the applause, because she is thinking about other duties she has to fulfill: she did not succeed in rescuing the boy who trusted her. The relation between art and life appear to be complex and hard to measure. There is also a confrontation between jazz and classical music, which teaches us something about the character and profession of Fiona's trained incapacity, that is, she can't play jazz: "No pulse, no instinct for syncopation, no freedom, her fingers numbly obedient to the time signature and notes as written. That is why she was studying law, she told her lover. Respect for rules" (*Children Act* 193). McEwan confronts both perspectives as a trained incapacity or an occupational psychosis through musical preferences.

In general, the novel focuses on the ethical decisions we inevitably have to make in life. The story illustrates the complexity of rules and interventions, combines the personal and the social, and gets inside the law and can be read as a kind of ethnography or, indeed, equipment. It shows the power and complexity of storifying the world: "*The Children Act* presents a scenario in which the virtues of the secular life, poetry included, fight against the consolations of religious belief and no winner is declared. All the things that Fiona lives by—most importantly, music and the law—are found in some way wanting. It may be a different, more supple and surprising argument but it is an argument nonetheless" (Robson). Again, the role of art is thematized in the novel, and both novels thematize the role of literature: "McEwan may disdain belief in the supernatural, but the powers he claims on behalf of literature must also be taken on faith" (Friedell).

Conclusions

As far as the debate between the two cultures is concerned, McEwan seems to follow the suggestions of Snow in trying to bridge the gap between them: "Although he never explicitly refers to C. P. Snow, it seems that of all contemporary novelists writing today, he is the most devoted follower of Snow's recommendations" (Fabiszak et al. 449). On the other hand, he follows up the arguments of Leavis and reflects upon the function of literature.

McEwan participates in the debate about the two cultures with novels with essayistic ambition on the one hand, but on the other hand, as we already stated above, he accommodates facts and arguments "into a prose that resists being candidly discursive" (Robson). The fact that McEwan uses the novel as a vehicle to reflect upon the relation between art and science implies that he uses the novel as a kind of allegory to discuss major social and cultural problems. Both works of McEwan that we discussed can be read as part of an ethical turn in literature and a revival of humanism in twenty-first-century literature. Both novels reflect upon traditional humanistic values in general and the function of literature in particular. In an interview McEwan presents a perspective on the purpose of the novel:

> The novel is famously good at revealing, through various literary conventions, a train of thought, or a state of mind. You can live inside somebody else's head . . . I think that quality of penetration into other consciousnesses lies at the heart of its moral quest. Knowing, or sensing what it's like to be someone else I think is at the foundations of morality. I don't think the novel is particularly good or interesting when it instructs us how to live, so I don't think of it as moral in that sense. But certainly when it shows us intimately, from the inside, other people, it then does extend our sensibilities. ("Ian McEwan")

From this perspective of "extending our sensibilities," McEwan's work can be read as an analysis of the struggle between sense (rationalism) and sensibility (emotionalism) (De Canha), so he problematizes and thematizes the perspectives of the two cultures confronting the reader with "a perspective of perspectives" (Burke, *Grammar of Motives* 513) through literature.

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Chapter 6

The Missing Link and Human Origins: Understanding an Evolutionary Icon

Peter C. Kjærgaard

Abstract

In the history of evolutionary theory no single topic has attracted so much attention and caused so much public debate as the question of human origins. In the discussions following the discovery of hominin fossils in the late nineteenth and early twentieth centuries, the idea of the missing link between humans and animals turned into what has historically become one of the most powerful icons of evolution. Until the mid-twentieth century, however, both adherents and critics of evolution hailed the missing link as a crucial proof of the correctness of the theory of human evolution. It continued to be a hot topic in public debates and, as such, a good selling point for popular science books equally exploited by journalists, professional science writers, and scientists. Despite the fact that the idea of a missing link as a necessary piece of evidence for human evolution bears no meaning in contemporary science, it is wrong to think that it has no relevance. The missing link's lasting effects on public understanding of human evolution has made it far more than a mere cultural product, and thus it continues to be a problem in public engagement. This chapter presents a brief history of the missing link as an evolutionary icon in popular and scientific contexts.

No Need for Introduction

In a decisive scene in the animated blockbuster film *Monsters versus Aliens,* the transformed giant, Susan, feels compelled to point out to her fellow monsters how special they are. While addressing a bigmouthed and somewhat reckless character she exclaims: "And you, you hardly need an introduction. You're the missing link!"[1] Indeed, the missing link does not need an introduction for a twenty-first-century audience. We know the missing link and we even know him so well that we are able to recognize him—almost always a male—in multiple forms and contexts. Invoked in the nineteenth century, cultivated and celebrated in the twentieth century, and all too familiar in the twenty-first century, the missing link has been and still is one of the most powerful icons of evolution.

The missing link, everybody knows, is the key to the riddle, the final piece of the puzzle, the evidence that links us humans to the rest of the animal kingdom and finally proves the connection to our evolutionary past. In popular culture, the missing link is all that, epitomized as the ultimate proof of human evolution. Surely, missing links understood as gaps in the fossil record are not exclusive to the human story, and other species' missing links have routinely been reported and duly discussed. But the big prize, the winner-takes-all of paleontology, has always been connected to our own story. And for all things unique—such as freedom, liberty, culture, national identity, god, and human—the missing link takes multiple forms. We know the idea of the missing link. We understand it and can relate to it depending upon our own context. But we always recognize it, just as we recognize and can relate to the ideas of freedom, liberty, and the pursuit of happiness, and yet interpret them in so many different ways. The missing link is a potent idea, a concept and an icon that has captivated public imagination for now about 150 years. As Susan, the giant animated woman said, the missing link hardly needs an introduction. What the missing link needs, however, is history and context.

Shortly after the publication of Charles Darwin's *Origin of Species* in 1859 the missing link became a household expression in scientific and public debate about human origins. Satirical journals such as *Punch* made casual references to the missing link from the 1860s. *The Times* reported in 1866 that "the Darwinians" were searching for it, and the expression was regularly invoked at meetings of *The Anthropological Society* in London (see, e.g., "The Missing Link," "The Domestic," "The Fifeshire," "Reports"). In the 1890s the Dutch physician Eugène Dubois set out on an expedition with the explicit aim of finding the missing link and to prove the theory of evolution true. The English biologist

E. Ray Lankester seconded its importance in 1915 in the discussions about "the Piltdown Man," and in 1924 it played a decisive role as the American fundamentalist William Jennings Bryan thundered against evolution. That same year the anatomist and Australian expat Raymond Dart discovered *Australopithecus africanus* in fossil rich rocks brought to him in his home in South Africa. He was convinced himself that he finally found the missing link (Dart; Kjærgaard, "Hurrah"; Lankester; Numbers, *The Creationists*; Reader; Shipman).

By finding the first fossil evidence of ancestral humans in Africa, Dart's discovery has been seen as marking the beginning of the modern study of human origins and the gradual dismissal of the missing link as a scientific problem. Yet, the missing link continued to turn up in various contexts from the scientific literature to popular culture and debates about science and religion. Scientists, capitalizing on the idea, found the missing link to be a good way to attract a larger audience for their popular writings. In that sense there is a direct line from Raymond Dart's memoirs, *Adventures with the Missing Link,* to Colin Tudge's *The Link: Uncovering Our Earliest Ancestor,* accompanying the study of *Darwinius masillae* in 2009 (Dart and Craig; Tudge and Young; Franzen et al.). Embracing the concept for a popular audience and dismissing it in scientific circles, however, has made the missing link ambivalent, if not directly damaging, with respect to public understanding of evolution. Simultaneously endorsing and relegating the missing link has thus added to the already many mixed messages about evolution in the public sphere, making it notoriously difficult to assume the authoritative position of a scientific consensus in the context of public engagement.

Common Misconceptions about Evolution

Rejecting the necessity for critical evidence in the shape of not yet discovered fossils, on the one hand, while capitalizing on the idea of a missing link, on the other, has accordingly reinforced the public image of a scientific community divided on a key point in evolutionary theory. As such, it ties directly into a series of widespread myths and misconceptions about evolution. Many originating already in the nineteenth century, some of these myths are maintained today by anti-evolutionist partisans through websites and other media, but mostly they are a result of basic misunderstandings about how scientific knowledge is produced and confusion about standard concepts of evolutionary theory. They range from believing that the theory of evolution is an explanation for the origin of life to difficulties in understanding natural selection and common ancestry. They appear in the classroom, in media coverage of topics related to evolution, and in public debates. Creationist propaganda, then, does not pose the biggest problem in education and public engagement.

However, the great pedagogical potential in these misconceptions should not be underestimated. Challenging them has proven to be a useful tool in education and public understanding of evolution. One of the reasons why this approach has been successful is because challenging widely held beliefs about evolution feeds straight into students' and audiences' preconceived notions, taking advantage of a natural engagement in questions directly relevant to individuals and specific life situations. Some university-based public engagement projects at, for example, University of California, Berkeley, and Aarhus University, have integrated this as a part of their online evolution outreach commitment.[2] Others have experimented with the approach in different contexts, bringing it into the classroom from primary school children to undergraduate students at universities, and taken it as a starting point for engaging in public debates (see, e.g., Abraham et al.; Andersen et al. Andrews et al.; BouJaoude et al.; Branch and Meikle; Cunningham and Wescott; Gregory; Nadelson; Nehm et al.; Numbers, *Galileo*; Pazza et al.; Sinatra et al.; Thagard and Findlay). One of the important lessons from these studies is that regional and national contexts matter in identifying and overcoming the barriers in student and public understanding of evolution. On the other hand, there are certain conceptions and ideas that, despite locally different interpretations, come across and form a general pattern of misunderstanding:

- Evolution is like climbing a ladder
- Evolution is just a matter of chance
- Organisms are always fighting and trying hard to adapt
- Natural selection gives organisms exactly what they need
- Evolution is "just" a theory
- The theory is threatened by gaps in the fossil record
- There is widespread scientific doubt about evolution
- The theory has a shaky foundation
- It is not a science because it cannot be observed or tested
- Evolution is incomplete, unable to give a full picture
- The theory is flawed, but scientists are not willing to admit it
- It is necessary to keep a balanced view of evolution and creation

The question of human origins is generally identified as one of the main barriers in public understanding of evolution, and many misconceptions feed directly upon this problem (Blancke et al.; Szerszynski; Numbers, *Science* 11–37). This was already the case in the immediate public aftermath of the publication of Darwin's *Origin of Species* (Ellegård 332). The general question of gaps in the fossil record is pertinent in this context as the missing link signifies the fossil evidence of the connection between humans and all other animals. It has been seen as a threat to human uniqueness, the scientific proof to dismiss a hierarchical structure of nature, and something that will change our understanding of humanity and what makes us human. The missing link continues to play this role as it challenges our perception of the animal-human boundary and of who we are (Corbey). Thus, this particular alleged gap in the fossil record has received remarkable attention in the cultural history of evolutionary theory. It relates to the idea of progress and the notion that evolution is like going up a ladder. Modern humans represent the final stage, with each intermediate stage representing earlier and more primitive ancestors. The missing link would be the stage just after the one in which the great apes stopped evolving and remained the apes they were as the path was cleared for *Homo sapiens.* Already in the nineteenth century, following the frontispiece of Thomas Henry Huxley's *Man's Place in Nature,* published in 1863, the image of a line of apes leading up to modern humans became synonymous with human evolution in a popular context. Huxley had chosen a series of ape skeletons from gibbons, orangutans, chimpanzees, and gorillas to compare with a human skeleton to illustrate the similarities and close family ties among the primates. As more primate fossils were discovered, the apes were substituted with potential human ancestors. Over the next century and a half this image went through thousands of variations and is still today easily recognizable across cultural and geographical contexts (figure 6.1). It fits the popular image of the caveman and occasional cavewoman. The assumptions underlying these depictions are not limited to popular contexts, however, and have had a serious influence on scientific interpretations of fossil evidence, artifacts, and reconstructions of prehistoric life (Berman; Wiber).

Gaps in the Fossil Record

Missing links were known before Darwin. The idea of arranging animals hierarchically in a nature's ladder, *scala naturae,* dates back to Aristotelian classification systems and was later used as a foundation for European taxonomy. The Great Chain of Being made order out of nature, while also pointing to potential gaps in the chain. In *Vestiges of Creation,* published anonymously in 1844, Robert Chambers used "missing links" to denote gaps in the fossil record in an

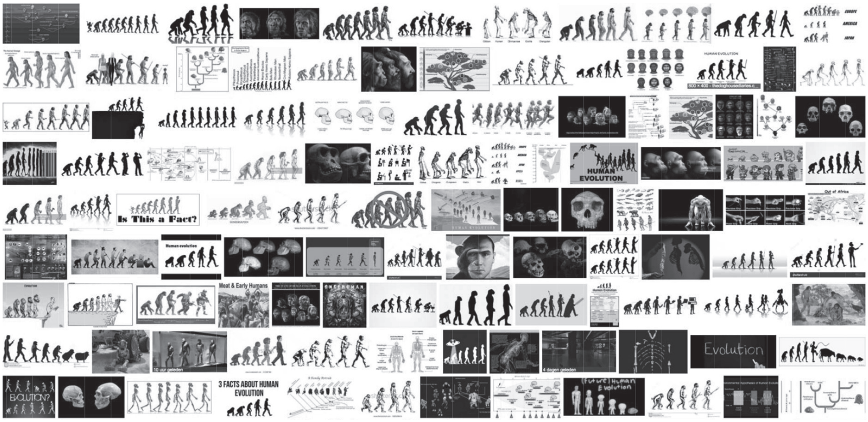

Figure 6.1 A Google images search of the term "human evolution." Identical search results is achieved from all continents.

evolutionary framework. The expression, however, was already widely used in other contexts and had no particular bearing on natural history. Like so many other words and expressions, it continued to have multiple uses and meanings (Kjærgaard, "Hurrah").[3]

However, after the publication of Darwin's *Origin of Species,* missing links were more often tied to questions of evolution, in particular human evolution, as the issue of gaps in the fossil record entered a discussion of the validity of evolutionary theory. In the following decades of the nineteenth century, it was a serious concern for a number of naturalists, but eventually the argument died out as a scientific problem. In popular and nonspecialist contexts, however, it remained a contentious matter through the twentieth century and still plays a role in the twenty-first-century public understanding of evolution. In creationist arguments it has continued to be one of the key objections to the empirical foundation of the theory for more than a century and a half.

Darwin himself addressed the question already in the first edition of *Origin of Species:* "As on the theory of natural selection an interminable number of intermediate forms must have existed, linking together all the species in each group by gradations as fine as our present varieties, it may be asked, why do we not see those linking forms all around us?" He considered this to be "the most obvious and forcible of the many objections which may be urged against my theory" (Darwin 462–63). His answer was that the geological record was far more imperfect than most contemporary geologists were prepared to believe. The museum collections represented but an insignificant fraction of extant and extinct species. Although more fossils would be found, adding to the great picture, sometimes with specimens that could be considered linking two previously identified species, one had to accept that the fossil record was not complete and could, thus, not form a complete picture of an unbroken chain. Nor was this necessary, Darwin argued, as the converging evidence, which included but was far from reduced to the fossil record, pointed to gradual change over very long spans of time as the only possible explanation for the variation of life on earth. The argument of converging evidence demonstrated the power of an interdisciplinary approach that has been at the core of evolutionary studies ever since. It rendered redundant the idea of a need for one decisive piece of evidence to prove the theory. Finding a missing link would not prove evolutionary theory correct once and for all; and not being able to produce one did not challenge the theory either.

Religiously motivated criticism of Darwin proved to be largely immune to the argument of insignificance of missing links for evolutionary theory. Converging evidence or not, Darwin's readers were asking for an answer to the question of where the links were, why they were missing, and what one was expected to do about it. Commenting on discussions between Thomas Henry Huxley and Robert Owen at the British Association for the Advancement of Science meeting in Cambridge in 1862, a strong argument for human uniqueness was made in a leader in *The Times:* "It is conceivable, though improbable in the highest degree, that scientific research may discover what has presumptuously been called the 'missing link' between the human skeleton and the skeleton of the highest class of apes" ("London"). Although the immediate cause was the ongoing debate between evolutionary champion Huxley and critical anatomist Owen, the broad target was Darwin and his followers. Owen was given all the credit as the highest authority, while Huxley and the evolutionists were dismissed as "no basis but a set of disputed facts which cannot possibly prove more that that something which was not human once existed in human shape. It is one thing to show that a brute may have organs as perfect as man; it is another thing to prove that man is nothing but a highly educated brute" ("London"; see also Kjærgaard, "Hurrah" 89–91). The argument against the evolutionary hypothesis and implications for ideas about humanity's place in nature resonated well in the conservative press. It was copied verbatim a few days later in *News of the World* and variations continued to play a role in the network of debates in numerous media and on several platforms.

The missing link arguments in the British periodical press against evolution in the years following the publication of *Origin of Species* fall into six categories: arguments regarding transitional forms among extant species, experimental evidence, historical evidence, paleontological evidence, insufficiency of geological time, and want of contemporary species turning into other species (Ellegård 216–41). Generally the evolutionary explanation was seen as altogether hypothetical and lacking positive evidence. Critics pointed out that one did not see the innumerable transitional forms among present species and that no one had ever witnessed one species transforming into another. No whale ever turned into a monkey, for example. There was neither experimental nor historical evidence to support the claims, and furthermore, it was argued from many sides, there simply was not time enough in the history of the earth to produce the innumerable missing links.

The most important argument, however, remained the problem of gaps in the fossil record. The inclination to make positive conclusions from negative evidence worked well in the popular press and made the missing link argument an effective rhetorical device for anti-Darwinians. As all of the arguments were based on misunderstanding both the theory of evolution itself and the implications it had, the most effective strategy to answer the critics seemed to be more and better information. Supporters of evolutionary theory certainly tried that, but were largely unsuccessful in the parts of the periodical press already prejudiced against the theory. The more biased against Darwin's ideas a journal or magazine was, the less likely was it to print impartial information. Despite the surge in the sheer number of periodicals in this period and the liveliness of debates, discussions tended to keep within rather conservative boundaries, maintaining positions and conforming opinions. Attitudes did not change quickly within individual periodicals, neither among the editors and members of the writing staff, nor among their readers (Kjærgaard, "Within").

Based upon his pioneering study of Darwin and the general reader in the British periodical press, Alvar Ellegård concluded that "anti-Darwinianism led to the Darwinian theory to be caricatured, and the caricature perpetuated anti-Darwinism" (241). As most of the periodicals ran a protective editorial line pandering to the cultural and religious prejudices of their readers, many of the arguments were never tried in an open academic environment leading, indeed, to parallel discussions in public culture and conservative Christian groups with little connection to the consensus forming in the scientific establishment. Originating in the nineteenth century, this trend has continued to play an important role into the twenty-first century, propagating discussions about missing links and gaps in the fossil record as problems for evolutionary theory, even though such objections have long been obsolete in science.

Initially, however, the issue of gaps in the fossil record was taken seriously by members of the scientific community and among the more adventurous it was regarded as a challenge to be met. The search was in full swing, and in the decades following the publication of *Origin of Species,* paleontological accolades were intimately linked to finding missing links. The sensational unearthing of *Archaeopteryx* from Bavarian limestone in 1861 was a great encouragement in that regard. With wings, feathers, and hollow bones like a bird, and teeth, legs, and a tail like a dinosaur, it immediately became a fossil celebrity and one of the earliest icons of evolution (Wellnhofer). As missing links go, *Archaeopteryx* was great, but the scientific community and the public were still waiting for the ultimate prize, *the* missing link, the human species' immediate ancestor and direct link to a simian origin.

During the nineteenth and twentieth centuries there were many contenders, both in the scientific world and in popular culture. Indeed, the idea quickly assumed a life of its own, independently of scientific discussions and findings, but it was still a powerful and influential paleontological hypothesis feeding back into scientific circles profoundly shaping interpretations, aspirations, and individual careers. Out of a nineteenth-century fascination with the exotic, the unfamiliar, and sometime the dangerous, represented in traveling exhibitions of peoples from around the world, bizarre skeletal constructions, and monkeys and apes on display, the missing link grew into a familiar cultural idea appearing in illustrations, cartoons, photographs, articles, short stories, novels, popular science writings, advertisements, and eventually in radio programs, television shows, films, and a multitude of twenty-first-century electronic media (Kjærgaard, "Hurrah"; Clark, *God*; "You Are Here"; Edwards; Voss; Goodall) (see figure 6.2).

The Missing Link in Popular Culture

Even though it is with great familiarity that the missing link is introduced in *Monsters vs. Aliens,* there is something not quite right here. We are looking at a 20,000-year-old fish-ape hybrid that scientists found in a block of ice where he had been hibernating in a good long cryosleep. As the scientists thawed the ice he came back to life, a bit out of shape and with back problems, but otherwise fit for a monster fight and starting out scaring the wits out of people on holiday at a place that used to be his natural habitat; a lagoon thousands of years ago, a resort today. All is good fun loaded with irony and references to popular culture such as the 1950s horror classic *Creature from the Black Lagoon*.[4] But the film

Figure 6.2 A Google NGram search of the term "missing link" in digitized books from 1800 to 2000 demonstrate a surge following the publication of Charles Darwin's *Origin of Species,* peaking in the years after Darwin's death and the continued public debate about evolution and humans' place in nature. Over a century it remains stable to climb again from the 1970s, coinciding with a renewed focus on human evolution through highly publicized fossil remains such as the *Australopithus afarensis* known as "Lucy" and others, and a series of creationist court cases. The graph is not cleaned for nonevolutionary references to "missing links." The term is indeed used in other contexts, but the vast majority of references are in the context of evolution.

twisted the standard missing link and replants it in a context that, despite the monster theme, was inoffensive for an American market heavily influenced by anti-evolution sentiments ranging from mild scepticism to aggressive creationism. A missing link not insisting upon an ape ancestry and a deep evolutionary past is simply a lot safer for family entertainment than a traditional missing link. Here were no hairy reminders of simian relatives. Dreamworks' missing link is fun, green, and harmless, a monster for love and laughter. That has definitely not always been the case for the missing link.

As the shady nanny Debbie Jelinsky watched Fester Addams emerging from the rubble of the suburbian mansion she had just blown to pieces in *Addams Family Values* (1993), she exclaimed: "Oh, do I love you? Look at yourself! You're a nightmare. You're the missing link. You shouldn't be married. You should be studied."[5] Although sympathy lies with Fester, we understand Debbie's metaphor. It works because we recognize the missing link as an abhorring creature, equally an object of disgust and of scrutiny, and most certainly not an object of love. The history of the missing link is a history of this dialectics of repulsion and fascination that, curiously, has functioned well in popular culture as well as in the scientific literature from the nineteenth into the twenty-first century.

The idea of the monstrous and the powerful iconography of the half-human and half-animal that has played such an important role in cultural representations and mythology from the Egyptians to the Greeks to the early modern period, through the enlightenment to the nineteenth century, all along generating scientific scrutiny and public fascination, was appropriated across the board in popular culture to discuss evolution and humans' place in nature. The missing link was perfect to capture deep ancestry and the complexity involved in negotiating the human-animal boundary (Corbey; Corbey and Theunissen). Movie-makers quickly saw the potential and seized the missing link as a popular sidekick or sometimes central character, but mostly among the villains in Tinseltown.

Thomas Edison's stop motion short, *The Dinosaur and the Missing Link: A Prehistoric Tragedy* (1917), is a classic comic hero tale. The missing link, a gorilla-like creature with the name Wild Willie, goes down to the river to catch a few snakes for dinner. Unfortunately he mistakes a dinosaur tail for a snake and hits it with a rock. The dinosaur does not take kindly to the attack and kills the missing link. The hero comes by, finds the dead missing link, takes the honor and gets the girl, the young and beautiful Araminta Rockface. Already an integrated part of popular culture, the fictional prehistoric world of cavemen and dinosaurs living in the same primitive environment was a perfect setting for encounters with the missing link. With an easily identifiable iconography, prehistory thus became a space for sex, satire, and discussions of gender, race, ethnicity, society, and social norms (Berman; Clark, *God*; "You Are Here"; Moser, "Visual"; *Ancestral*; Wiber).

The missing link on film—always male—continued to be the bad guy. Sometimes comic, sometimes scary, he invariably invited viewers to look their own primitive past straight in the eyes. As such, the missing link was more of a contemporary cultural reflection than an artistic exploration of a scientific notion of deep evolutionary ancestry. Too esoteric to constitute a subgenre, missing link films were closely related to ape movies and prehistoric fantasies. Often constituting a theme, a sidekick, or supporting character, the missing link served as an opportunity to negotiate the human-animal boundary and the use of prehistory as a mirror to reflect contemporary issues. Ape movies from *King Kong* (1933, 1976, 2005) to *Planet of the Apes* (1968, 1970, 1971, 1972, 1973, 2001, 2011, 2014) routinely integrated missing link themes as a connecting point between humanity and animal nature. In the original *Planet of the Apes* (1968), the female ape scientist, Dr. Zira, hypothesizes that the stranded astronaut Taylor could be the missing link between unevolved primates and apes, reiterating the theory of her fiancé, the ape archaeologist Dr. Cornelius, that apes evolved from a lower order of primates, possibly humans. The ironic twist on the widespread popular understanding of human evolution as a matter of humans descending from extant apes was taken further as Zira and Cornelius were charged with scientific heresy for suggesting such an idea. The missing link theme lived on in the series echoing the original 1968 protest from the astronaut—"I am not the missing link!"—in Tim Burton's 2001 adaptation.

Independence, the right to be a species in itself not defined by humans or humanity, and the claim to be recognized as an individual lies at the heart of the popular reconstruction of the missing link. It is always in vain, however. The missing link always loses. Brute, beast, noble savage, the missing link is relevant only because it is linked to human history. In itself it is nothing. This might not be fair, but this is how it is. When things are turned upside-down and humans are seen as missing links in the *Planet of the Apes* series, it points to the injustice of classifying everything in the world according to our own standards. It works because it reflects how we view the rest of the animal world. Mostly, however, in popular culture the missing link is spectacular, extraordinary, challenging, but rarely ironic.

A notable exception is an advertising campaign by the American car insurance company, Geico, from the 1990s. Playing on sensitivity to political correctness, the company's faux campaign introduced the slogan, "so easy a caveman could do it," by a sleazy advertising agent in a supposedly authentic film studio. A cameraman who turned out to be Neanderthal walked out on the set with the words "Not cool!" The campaign became quite successful using civilized Neanderthals as an ironic take on our perception of ourselves and minorities. It worked because the image of the primitive caveman is so ingrained in popular culture that no explanation was needed. They were Neanderthals. They could just as well have been missing links, and in a way they were.

Live missing links were often put on display at fairs and on tours in the nineteenth and twentieth century. It was part of the tradition of traveling exhibitions featuring peoples from around the world in traditional clothing, with cultural artifacts showing stereotypical images of exotic ethnic groups to Europeans and North Americans. A famous example of a "living missing link" is Krao. She was a child suffering from hypertrichosis, abnormal hair growth, who was brought from her native Laos to Europe by the Norwegian naturalist and collector Carl Bock, author of *The Head-Hunters of Borneo*. She was taken on by William Leonard Hunt, who under the pseudonym Signor Farini capitalized on evolutionary ideas and promoted her as "The Missing Link: A Living Proof of Darwin's Theory of the Descent of Man." She was introduced to the London public in 1882. Two years later she was a box office success touring the United

States. She kept her public role as an accomplished "missing link" for over forty years, speaking five languages and playing the piano (Goodall 74–79).

Krao was not alone. Numerous hairy and indigenous people were put on display. In southern states in the US, African Americans occasionally played the same role at fairs, and apes, mostly chimpanzees, were promoted to prove evolution or simply to raise attention. Combining sensationalism and evolutionary theory, and often including racial hierarchies, living missing links were exploited to make money on curiosity, prejudice, and a Eurocentric feeling of superiority. It included all the well-known colonial elements of racism and abuse. It was terrifying and comforting at the same time, reminding viewers of the animal nature and potential origins of humanity while assuring them that they were safely civilized.

The End of the Missing Link

Scientifically, it makes no sense to talk about one missing link, or missing links in general. Darwin and his contemporaries did, but they worked within a different conceptual framework, with the Great Chain of Being still being something that had to be addressed. And even nineteenth-century evolutionary naturalists were often wary of using the term, many fully aware of the misrepresentation and potential dangers of emphasizing particular fossils as more special than others. From an evolutionary perspective, every single creature and every single plant is just as special as another. What makes some stand out is our understanding and limited fossil evidence—the gaps in the fossil record. Darwin was concerned about how to handle them, but less from a scientific point of view and more from the perspective of how it would be perceived. In that sense he was very much aware of the power of public understanding of science, even though that term only became a household phrase by the end of the twentieth century. Evolution means gradual change over time. It emphasizes continuity rather than breaks. Even the theory of punctuated equilibrium suggesting isolated episodes of rapid speciation between long periods of little happening, initially proposed by Stephen Jay Gould and Niles Eldridge in 1972, does not imply discontinuity. Evolutionary bottlenecks triggered by environmental, geological, or anthropogenic causes do not mean that one moment you have one species and the next you have another completely different one. It means that certain populations are favored, more or less depending on external factors, and that certain traits of isolated groups can thus be boosted. Already Darwin knew that. It also means that no single species represents all the change misconstrued in the idea of transitional forms. There is no quadruped ape one moment and a bipedal ape another. Despite that, the missing link is alive and well. Sometimes inevitably so owing to a hyperbolic sensationalistic press more interested in grabbing attention than communicating complex research results. But sometimes also because scientists behave opportunistically and employ missing links to achieve short term goals (Kjærgaard, "The Darwin" and "Ida").

Measuring the impact and significance of the missing link is difficult. Despite its scientific irrelevance it is hard to get rid of. In the context of evolutionary thinking, it has had a rich life spanning three centuries and there are no signs of it disappearing. As a standard reference used to debunk evolution it continues to play a central role in creationist arguments. In public discourse outside religious contexts it persists in capturing popular imagination. A familiar shorthand in the media it remains a point of reference, and it is still a successful attention grabber for scientists who wish to tap into the news stream. There is no such thing as a missing link in evolutionary theory. And yet there is no end to it.

Notes

1. The hugely popular *Monsters vs. Aliens* from DreamWorks Animation, directed by Conrad Vernon and Rob Letterman, was released in the early spring of 2009. It became the second highest grossing animated film in North America that year and the third highest worldwide.
2. Berkeley's *Understanding Evolution* has a section on misconceptions with English, Spanish, and Turkish versions (http://evolution.berkeley.edu/evolibrary/misconceptions_faq.php). Aarhus University's *evolution.dk* presents a slightly different approach, incorporating design and language adjusted to meet the target audience among secondary school children (http:/evolution.dk/myter). The Danish Darwin Archive presents common Darwin myths, available both in English and Danish (http://darwinarkivet.dk/en/myths).
3. Caution is required to avoid presentism in conceptual history. Historians, and perhaps especially intellectual historians, tend to overemphasize conceptual interpretations in their fixed sense, thus confirming what they are looking for and overlooking different uses that are abundant. See, for example, Patricia Seed's excellent history of the concept "Modern" (Seed).
4. *Creature from the Black Lagoon* was directed by Jack Arnold and released by Universal International Pictures in 1954.

5. *Addams Family Values* was directed by Barry Sonnenfeld and released by Paramount Pictures.

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Part 2

Cognitive Perspectives

The cognitive science of science investigates how human minds generate, process, sustain, and transform scientific concepts. The basic idea is that the human mind does not constitute a blank slate, but comes equipped with intuitive expectations about relevant domains of the world around us. In science, these intuitions play a twofold role. On the one hand, they pose cognitive obstacles that scientists need to overcome using various tools. On the other, when addressed appropriately, they function as scaffolds for a scientific understanding of the world. Thus, a cognitive approach also sheds important new light on the rhetorical perspectives developed in the first section of this volume. Science educators and communicators tend to explain highly counterintuitive scientific concepts and theories by employing intuitively appealing and thus more easily digestible arguments, images, and metaphors. By so transforming scientific concepts, they aim at recruiting people's intuitions to instill a scientific understanding of the world around us. However, this strategy generates rather than avoids intuitive interpretations of scientific concepts and theories. Each of the contributions to this section examines and discusses one or both of the roles intuition plays in the development, communication, and understanding of science. As such, the volume contributes to the burgeoning field that investigates the impact of human cognition on science, science education, and the public understanding of science.

Chapter 7

Suspicion toward Science and the Role of Automatic Intuitions about Origins

Elisa Järnefelt

Abstract

This chapter discusses how early developing automatic intuitions about purposefully made and functionally fixed natural phenomena can affect people's understanding and receptivity to scientific concepts, such as *evolution* and *anthropogenic climate change,* that involve abandoning many of the automatic hunches that people spontaneously possess about their environment. In addition to discussing these automatic intuitions, this chapter also considers how these intuitions may play a role in people's trust of the scientists who form and present the scientific information to the public, and how scientists could tackle the challenge of communicating about science to the public in an accurate and welcoming way.

Sometimes, being a scientist is a difficult thing. After publishing *On the Origin of Species* in 1859, Charles Darwin was not ed only in academic circles. He served also as a constant inspiration for the numerous cartoons and caricatures presented in popular culture. These drawings often depict Darwin as an ape, or an ape that is Darwin's close relative just a few generations away. In other drawings, evolution is depicted as a nonsensical dream or hallucination in which a worm evolves into an ape that develops into a human that finally turns into Darwin, or in which a fork transforms into a man, an oyster into a woman, and a wine bottle into a priest who marries the man and the woman. (Browne; Bryant) As is often the case with caricatures or parodies, besides being comical, these drawings have a cruel intention (Browne). Transforming a person or an idea into a joke sends a powerful message; it can diminish the authority or trustworthiness of the person as a reliable informant and question whether her or his ideas should be taken seriously. Darwin was neither the only nor the last naturalist whose credibility and reliability has been questioned in such a manner. More recently, for example, environmental scientists have experienced their fair share of doubt and distrust; particular groups do not just doubt the existence of anthropogenic climate change but feature it as pseudoscience, hoax, or conspiracy theory (Hmielowski et al.; Leiserowitz; Lewandowsky et al.). The similarities between the theories of evolution and anthropogenic climate change do not end here. In addition to suspicion toward naturalists and scientists, everyday reasoning about both conceptions appears similar. Instead of understanding physical-causal mechanisms, both natural processes are often construed in terms of purposes and intentions. For example, adults commonly construe evolution as nature's helpful response to animals' wants or needs (e.g., Gregory; Kelemen, "Teleological"). Similarly, anthropogenic climate change is often understood in relation to a purposefully behaving being, such as Nature, Earth, or God (Corner et al.; Donner, "Domain" and "Making"; Mortreux and Barnett).

In this chapter I seek to understand why the reception of the theories of evolution and anthropogenic climate change share these similarities. Why does everyday reasoning about the origin of natural phenomena take a certain kind of shape? What makes an evolutionary or climate scientist suspicious and untrustworthy?

I start by assessing the previous notions that explain on a more general level what kind of information is more likely to succeed or fail in cultural transmission. After clarifying the essential role of automatic reasoning, I concentrate more specifically on the intuitions that both children and adults have about the origin of both living and nonliving natural phenomena. In reference to empirical research, I identify developmentally stable patterns in people's reasoning that remain automatically active later in life: a tendency to assess nature as functioning purposefully toward ends that benefit nature and remain fixed, and a tendency to think that even though ordinary people cannot create nature, some other kinds of beings can. Finally, I assess how these intuitions, together with the way people assess novel arguments, are likely to play roles in ways people accept and reject information about evolution and anthropogenic climate change and calibrate their trust toward people who communicate these ideas. In the end, I make some suggestions concerning more successful communication of scientific information.

The Shape of Culturally Successful Information

Why do people prefer and trust one kind of information over another? To better answer this question, it is necessary to acknowledge the difference between automatic intuitions and reflection (Sperber, "Intuitive"). This division refers to people's ability to form information via (at least) two different cognitive processes: system 1 and system 2. System 1 processes are instant, beyond one's conscious control, and produce representations about immediate reality. System 2 processes require full attention, reflection, and effort and are more slow and sequential but also allow one to assess, consciously endorse, or momentarily inhibit ideas that are automatically formed via system 1 (J. Evans, "Dual-Processing"; Stanovich; Kahneman; see also E. M. Evans in this volume).

Even though people would like to think of themselves as being able to think freely, they are rather predictable when relying on system 1 processes that are formed without being taught to think in particular ways (Barrett and Kurzban; Boyer and Barrett). For example, from very early on, people tend to think that agents, apart from other physical objects, have goals and intentions (e.g., Spelke; Wellman), that objects serve specific functions (e.g., Kelemen and Carey), and that certain kinds of animals, for example, all bears, share something similar that causes them to be fundamentally different from other kinds of animals or natural entities, such as whales, beetles, or spruces (e.g., Atran; Gelman). Rather than neatly following the lines of philosophical ontology (e.g., living thing, human-made artifact), system 1 automatic intuitions about the environment can be understood in terms of cognitive adaptations that refer to types of situations that have been stable in the human environment (e.g., detection of potential allies, prey or predator, identification of the potential function of an object). Simply put, humans, together with other animals, have fast acting intuitions—early developing and persistent tendencies through which they process information in particular ways—that can be understood to reflect recurring features of the environment (Boyer and Barrett).

One can wonder about the relevance of this—paying attention to the contours of automatically forming reasoning about the environment—for the assessment of culturally transmitted information. After all, even though people have intuitive and spontaneous reactions, they do not just blindly react to environmental stimuli but mostly rely on communicated information and are able to reflect upon their own thoughts to interpret the world around them via system 2. Partly, this is true. However, system 2 reflection does not occur in a vacuum apart from system 1 automatic reasoning; rather, the two modes of reasoning are interrelated. No matter the amount of practice and effort, inhibiting or erasing automatic reasoning from one's mind is impossible. Once the triggering stimulus appears, system 1 automatic hunches fire off "ballistically" in the absence of conscious control (Stanovich). Robert N. McCauley illustrates this with an example: one cannot avoid perceiving the Earth as flat while standing on the ground, no matter one's ability to remind oneself that actually the Earth is a huge revolving spherical object that is revolving around another round object (*Naturalness*). It is not until the thought is cognized that individuals can consciously assess whether they agree or disagree with their automatic understanding of the environment (J. Evans, "Dual-Processing"; Kahneman; Stanovich).

Given the sensitivity of system 1 automatic hunches, people often end up unconsciously overrepresenting a wider range of environmental information in terms of these intuitions (Sperber and Hirschfeld). For example, without the need for explicit teaching, people are highly sensitive in detecting the faces of other people. Besides effortlessly recognizing human faces, one cannot avoid seeing faces in clouds, wall sockets, and burned toast (Guthrie). The sensitivity of system 1 has effects on system 2 processing and cultural transmission of information as well. According to Dan Sperber ("The Modularity" and *Explaining*; Sperber and Hirschfeld), from the cognitive point of view, the differences in the ease of distribution of system 2 reflected ideas can be understood in terms of the contours of system 1 automatic intuitions; the reflective ideas that people easily recognize, adopt, and share are the ones that resemble initial reasoning domains. Social psychological research resonates with this; people are prone to show "confirmation bias," "positivity bias," or "my side bias" (e.g., J. Evans, *Bias*; Mercier and Heintz; Nickerson), meaning that they are overconfident in accepting information that is in line with their own reasoning and reject the information that potentially contradicts or falsifies their beliefs (Kahneman).

Sperber, together with Hugo Mercier ("Intuitive" and "Why"), discusses this kind of pattern in people's reflection in reference to "epistemic vigilance" (Sperber et al., "Epistemic"). People are cautious toward information that is transmitted by other people. Reliance on abstract cultural information and not having to learn everything in the world firsthand is obviously a great advantage. However, when relying on abstract communicated information or other people's accounts of reality, one is at constant risk of hearing someone who is misinformed, or even worse, is intentionally deceptive and lying. Given this, Mercier and Sperber ("Intuitive" and "Why"; Mercier, "Reasoning" and "The Social"; Sperber et al., "Epistemic") point out that people constantly watch over whether they can trust the information and the informant. What serves as an instant anchor are the thoughts one already has—system 1 automatically formed intuitions. Young children are already selective in their trust and doubt reliable informants or majority opinion when it violates untaught intuitive assumptions about the environment (Clément et al.; Seston and Kelemen). Similarly, adults are less likely to accept information if it is not in line with instantly remembered background information, if formation of spontaneous inferences based on the new information is difficult, and if the information is not accepted by most of their peers (Mercier, "Reasoning" and "The Social"; Mercier and Sperber, "Intuitive" and "Why"; Sperber et al., "Epistemic").

When detecting incoherence in communicated information, one has to decide between two options: lower one's trust in the speaker by doubting her or his competence or benevolence, or lower trust in oneself and revise one's own beliefs (Mercier, "The Social"; Mercier and Sperber, "Intuitive"). Of these two options, the first one is rather easy and quick whereas the latter—active reevaluation of one's own reasoning—is not likely to take place until one encounters a social disagreement and must defend one's own reasoning. For example, both children and adults perform better in tasks that involve questioning their automatic impressions if they have to find the solution in a group of members who initially disagree with one another. In contrast, a group of similarly minded people more commonly ends up supporting the already existing opinion (Mercier, "Reasoning"; Schwind and Buder).

To return to the particular question concerning the suspiciousness of the theories of evolution and anthropogenic climate change: it is now clear that to make the first step in understanding the cognitive roots of this phenomenon, one has to understand more about people's initial hunches on the origin of natural phenomena.

Initial Understanding about the Origin of Natural Phenomena

I approach this task on two levels. First, I review developmental research in order to see whether children's reasoning about the origin of nature shows reliably occurring and recurring tendencies. After this, I assess recent empirical research that has been conducted among different groups of adults to see whether these early developing reasoning tendencies remain active later in life (see Blancke et al., "The Implications"; Bloom and Weisberg; Coley and Tanner, "Common"; Kelemen, "Are Children" and "Teleological" for partly related accounts).

In line with the previous section, when it comes to reasoning about the origin of various objects and phenomena (e.g., artifacts, animals, plants, landforms, meteorological phenomena) as well as these entities' functional features, children's reasoning does not align with the philosophically or scientifically correct ontology (Boyer and Barrett). This does not mean that children are not excellent at, for example, separating artifacts and natural entities from one another (Gelman and Kremer). Neither does it mean that children would be unable to learn scientifically accurate physical-causal explanations about nature even at young age (e.g., Ganea et al.; Kelemen et al., "Young"). Instead, it means that children are prone to represent both artifacts and natural entities in a similar fashion, and that their intuitions about objects easily overextend beyond philosophically correct ontological categories (artifacts vs. natural entities) (Kelemen, "Are Children"; see also Wolpert, *Six*).

Let me elaborate. From very early on, children tend to approach and reason about both artifacts and natural entities in terms of intended functionality. These notions are not directly taught but formed in interactions with a typical human environment. For example, children are able to assess objects' functional structure and usability as an indication of the designer's intention (Kelemen et al., "The Designing"; see also, e.g., Casler and Kelemen, "Young"; Cimpian and Cadena; Phillips et al., "Learning" for examples of various implicit cues). In parallel to this, children often conceptualize not only artifacts but also natural entities as "made for" some specific functions that benefit the entity itself, other natural entities, or nature generally rather than endorse explanations referring to solely physical causes (e.g., DiYanni and Kelemen; Kelemen, "The Scope" and "Why" and "British"). However, rather than understanding everything in their environment as human-made (see Piaget), when reasoning about the origin of natural entities, children prefer ideas about superhuman or nonhuman beings, such as someone, God, or another natural entity (E. M. Evans, "Cognitive"; Gelman and Kremer; Kelemen and DiYanni; see Gervais et al. and Järnefelt for discussion).

In addition to being effortlessly formed, these intuitions about the intended purposes of both artifacts and natural entities are functionally fixed. This means that once a certain kind of object or entity is conceptualized as made for some purpose, children find it difficult to think that the object could serve any another function (e.g., Casler and Kelemen, "Young"; German and Barret; Kelemen and Carey; Vaesen). Here, the understanding of intentionality again plays a determining role. Around the age of five, children have come to realize that knowing the designer's, rather than user's, intention leads to knowing the true (fixed) function of an object (e.g., Kelemen and Carey). For example, if the object was originally designed to function as a clothes stretcher, it does not cease to be a clothes stretcher even if someone later discovers it and uses it unknowingly for exercising his back (Kelemen, "Intuitive"). Again, in parallel, once children map a natural entity as a certain kind (i.e., as a member of certain generic species [Atran], such as a member of bears, oaks, or bats), they understand the kind as inherently immutable and fixed, and reject the idea of partial membership (e.g., Cimpian and Erickson; Gelman; Keil).

Recent research has continued to assess whether these reasoning tendencies about fixed purposes and intentional design remain active on an automatic level of cognitive processing also in adulthood. That is, in case these conceptions have an automatic basis in the sense of unavoidable and constantly active system 1 processing, one should find that when relying on instantly forming cognitive processing, adults also form these ideas unavoidably. However, in case these reasoning tendencies are examples of automatized reflective reasoning that has become effortless due to repeated practice, these views should be absent among those adults who have practiced thinking otherwise (see McCauley, *Naturalness,* for differences between automatic and automatized reasoning). So, what happens when adults, who have contradicting reflective views, are put into situations where they have to rely on automatic reasoning in order to provide an answer?

A first line of research has assessed the automaticity of teleo-functional reasoning (Kelemen and Rosset; Kelemen et al., "Professional"; see also Banerjee and Bloom; Casler and Kelemen, "Developmental"; Heywood and Bering; Lombrozo et al.). When answering under a restricted timeframe, even professional scientists show an increased tendency to agree with teleo-functional statements that describe living and nonliving nature to function toward self- or nature-serving ends. This means that even years of scientific education and the constant use of a physical-causal explanatory framework does not completely remove the instant appeal of teleo-functional ideas, such as "rain falls in order to allow plants to grow" or "the sun makes light so that plants can photosynthesize" (Kelemen et al., "Professional"; see also Kelemen and Rosset).

A second line of research has assessed whether the notion that some being created nature is similarly automatically formed (Järnefelt; Järnefelt et al.). Here the focus of attention has been on nonreligious individuals who explicitly disagree with the idea that any kind of higher power, God, or gods have created nature. Studies in the United States and Finland show that, although religious adults endorse creation more than nonreligious adults do, when assessing pictures of living (e.g., giraffe, maple, pike) and nonliving (e.g., mountain, river, rainbow) nature, without having time to reflect upon one's own reasoning, nonreligious adults show a tendency to increasingly understand nature as purposefully made by some being. Responding to control items and to a separate control condition further clarifies that adults do not agree with just any stimuli, or with just any idea of a maker. In line with the distinction that children make, adults do not similarly think that ordinary people can originate natural phenomena (Järnefelt; Järnefelt et al.).

To combine and summarize these empirical findings, certain recurrent intuitions about the origin of natural phenomena can be recognized: (1) both children and adults have a tendency to assess nature as functioning purposefully toward ends that benefit nature and remain fixed, and (2) both children and adults have a tendency to think that even though ordinary people cannot create nature, some other kind of being can.

Echoes of Automatic Intuitions in Reasoning about Evolution and Anthropogenic Climate Change

How do patterns in everyday reasoning and suspicious reactions toward theories of evolution and anthropogenic climate change appear when assessing them in the light of automatic intuitions about purpose, functional fixedness, and intentional design discussed in the previous section? Here I argue that the patterns in people's acceptance and rejection of both of these theories become more understandable and predictable when assessed in reference to these intuitions. To illustrate this, I offer four examples of scientific conclusions that can be inferred based on the theories of evolution and anthropogenic climate change. After each conclusion below, I point out, in reference to current research, how people often reject or doubt these conclusions either partially or completely. I suggest that these patterns of rejection can be understood in reference to the previously discussed intuitions about intended functionality, as echoes of the contours of instant intuitive understanding of the origin of natural phenomena.

Conclusion 1: All natural entities are subject to change and extinction, despite the apparent benefits of their present functions.

Instead of accepting natural phenomena as ever changing, people are often more comfortable with accepting biological change within a kind as long as it does not lead to cessation of the function that the kind is understood to perform. For example, people more readily accept the idea that one kind of bear can evolve into another kind of bear than they do the idea of a common ancestry of bears and finches (e.g., E. M. Evans, "Conceptual"). In this line of reasoning, intuitive understanding of functionality and purpose is likely to play an informative role.

People often believe in function as the primary motor of adaptation (Kelemen, "Teleological"). This means that without knowing how to describe the actual mechanism of change, people often conclude that an entity's current ability to perform a beneficial function is the sole factor in why the entity or its trait exists (Gregory; Kelemen, "Teleological"). Furthermore, offering a stark contradiction to both conceptions of evolutionary change and the predicted consequences of anthropogenic climate change, once a biological trait is recognized to carry a beneficial function (e.g., coloration for camouflage, thick blood for coping with parasites), it is more likely assumed to remain stable or fixed across time; not only is the further prospect of evolutionary change seen as unlikely but also the prospect of extinction (Lombrozo and Rehder; see also Poling and Evans).

Conclusion 2: Nature's functioning also affects humans, not just nature itself.

In line with the tendency to presume nature's functioning as serving or benefiting nature itself (e.g., Kelemen, "Why"; Kelemen and Rosset), a distinction is often drawn between the sphere of nature and the sphere of humans. It is common to underestimate both the effects of evolution and anthropogenic climate change by excluding humans from being subject to either natural process. For example, people often assume that evolution applies only to nonhuman entities or organisms that are distant from people's habitat (e.g., E. M. Evans, "Conceptual"; Shtulman and Schulz; see Atran for a folk-biological taxonomy). Similarly, climate change is sometimes pictured as concerning only nonhuman animals and distant habitats (Doyle), and people often doubt that they have personally experienced global warming (Akerlof et al.).

Conclusion 3: Changes in nature can be explained without reference to a nonhuman or superhuman being.

Reasoning about evolution and anthropogenic climate change solely in terms of nonagentive or unintentional physical-causal processes is relatively rare. Instead, people—in both religious and secular cultural contexts—are prone to mix ideas of supernatural beings together with conceptions of evolution and anthropogenic climate change. For example, both evolution and climate change are often seen as purposeful creations, or as phenomena that are ultimately in control of a supernatural being (e.g., Corner et al.; Donner, "Domain" and "Making"; Legare et al.; Mortreux and Barnett). In addition to ideas that are culturally understood and labeled as religious, based on research, people commonly form ideas that share a similar cognitive structure about a being who is mysteriously (Sperber, "Intuitive") able to originate natural phenomena, although they use scientific or secular vocabulary. For example, in the context of the theory of evolution, it is common to describe nature, natural entities, evolution, or natural selection in terms of purposefully behaving beings who create the features or entities that are purposeful in a particular situation (e.g., Blancke et al., "From Ends"; Kelemen, "Teleological"; Moore et al.). When reasoning about anthropogenic climate change, people often assess nature or the Earth as a being that will eventually take care for natural entities or itself, and "always wins somehow" (Corner et al.; see also Connor and Higginbotham). Findings in studies about adults' automatic tendency towards teleo-functional reasoning and understanding of intentional design imply a potential relationship between these kinds of ideas and intuitive reasoning tendencies: beliefs in nature's agentive powers (e.g., belief in nature as a powerful being) independently predict an increased tendency to assess nature both as purposefully functioning (Kelemen and Rosset; Kelemen et al., "Professional") and purposefully made (Järnefelt; Järnefelt et al.). Notably, this is the case also among those individuals who identify as atheists and strongly disbelieve in any kind of higher power, God, or gods (Järnefelt et al.). This suggests that even though religious and secular identities are tied to different kinds of explicit belief systems, from the cognitive perspective, everyday understanding (in contrast to scientific understanding) about the origin of nature may be rather similar, even though people identify and label their views differently. Using scientific terminology does not yet guarantee that one reasons accurately in reference to the particular scientific theory (see also Guillo, this volume).

Conclusion 4: Changes in nature are causally linked to human actions.

Finally, relating especially to reasoning about anthropogenic climate change, while having a strong intuitive preference to think that nature is not caused by human actions (e.g., Gelman and Kremer; Järnefelt; Järnefelt et al.), the core idea behind anthropogenic climate change—that humans have a causal effect on changes in sea levels, reflective properties of clouds, winds, wild fires, or total animal populations (Karl and Trenberth)—is not likely to make instant intuitive sense but instead sounds implausible (see also Donner, "Domain" and "Making"; Rudiak-Gould).

A Cautious Listener Makes a Suspicious Scientist

In relation to the notions concerning cautiousness toward information that contradicts automatic intuitions, presented in the beginning of this chapter, the examples elucidate how the content of theories of evolution and anthropogenic climate change contradicts preexisting and instantly activating intuitions of nature's apparent purpose and design. Without denying the existence of many other—both cognitive and cultural—components, it is likely that intuitions play a role in people's suspicion toward both of these scientific theories.

However, in addition to violating or contradicting the intuitive content of information and eliciting cautiousness toward scientific ideas about the origin of natural phenomena, researchers also encounter another kind of disadvantage that is likely to even further elicit suspicion and distrust in listeners. As research shows (e.g., Kelemen et al., "Professional"; Coley and Tanner, "Relations"), it is good to remember that scientists are not in any way immune to these same automatic cognitive tendencies and confirmation biases. However, given that scientific reasoning takes place in an argumentative context, opportunities to restrict their everyday reasoning are greater; researchers have more chances to test their ideas in contexts in which they are more likely to experience disagreements (e.g., peer-reviewed journals, conferences) and reflect upon their own arguments more than they would in an everyday interaction (Mercier and Heintz; see also McCauley, "Scientific"). Given that this argumentative space is not shared in mainstream culture where these ideas are communicated, for members of the public it may seem that scientists fail to sound consistent and coherent. Incoherence is again likely to prompt members of the public to revise their trust in the speaker rather than in their own thoughts (see, e.g., Mercier and Sperber, "Intuitive"). In line with this, research has found that, independently of their worldviews, people calibrate their understanding about anthropogenic climate change based on how same-minded or in agreement scientists appear over the matter (Lewandowsky et al.; see also Connor and Higginbotham) (see figure 7.1).

People may be even more tempted to recalibrate their trust in evolutionary and climate scientists in contexts where information about evolutionary processes and anthropogenic climate change is used in practice and combined with technology. That is when science and scientists can appear as dangerous (Wolpert, *Is Science*). For example, this takes place both in the context of biotechnology and geoengineering. Interestingly, the resistance to both technological approaches is similar (Corner et al.). In the context of hybridization and cloning, opposition refers to these technologies as disgusting, unnatural, and immoral (e.g., Niemelä; see also Rozin). Even though the explanation behind negative reactions is likely to involve various components (e.g., negative associations to pesticides or occurrences in the history of science), acknowledgment of automatic intuitions

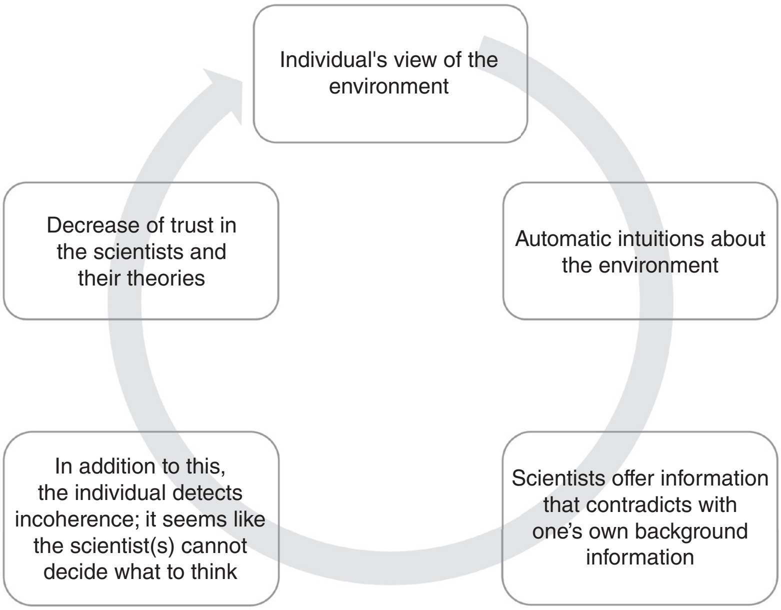

Figure 7.1 Recalibration of the listener's trust in scientific information about the origin of natural phenomena.

about fixed functionality and design may offer one additional layer of understanding about people's reactions. Namely, according to instant intuitions, it is not humans who create biological kinds, or mix one kind of an organism with another kind. Even though people seem to be open to artificial selection (e.g., breeding dogs) and hybridization within a kind (e.g., breeding mules that are the offspring of two horse-kind animals, donkey and horse), gene technology involving cloning and interspecies hybridization across different kinds of animals (e.g., human vs. nonhuman animal) does not just violate the intuition of the nonhuman identity of the maker, but also damages the notion of beneficial and fixed functions that kinds are understood to perform (see also Niemelä). Similarly, at the heart of the rejection of the use of technology to counteract the effects of climate change is the idea of "messing with nature"—going against the natural order (or fixed functionality) that nature has purposefully set. In this mental framework, defying the natural order is an immoral act that is understood to further elicit nature's revenge (Corner et al.).

In sum, it is not necessarily a complete coincidence that scientists are sometimes accused of "playing God" (Wolpert, *Is Science*); scientists can develop ideas that in practice violate people's automatic intuition of nature's beneficial functionality and also their intuition that a nonhuman being originated natural phenomena. In line with Wolpert's notion, here it is also good to emphasize that science and technology are not the same thing; evolutionary or environmental findings in science do not necessarily lead to technological applications, and evolutionary and climate scientists are not unavoidably involved with engineering. However, this distinction may not be fully clear to the public (see also McCauley, *Naturalness* and "Scientific").

Conclusion

In this chapter I have traced echoes of two automatic intuitions in reactions to the theories of evolution and anthropogenic climate change: (1) the understanding of nature as purposefully fixed in its beneficial functions that serve nature itself, and (2) the understanding of the origin of natural phenomena as purposefully created by some nonhuman or superhuman being. I conclude that these intuitions together with the cautiousness that people show toward novel arguments are likely to play significant roles in suspiciousness toward both the theories of evolution and anthropogenic climate change as well as toward the scientists who produce and communicate these theories to the public. How can scientists better communicate their findings and navigate through the potential prejudices that people hold?

Evolutionary biologist David Sloan Wilson ("Evolution"), who has initiated a university-wide evolutionary studies program at Binghamton University called EvoS ("EvoS"), offers one kind of solution for better science communication. EvoS does not require any prerequisites and is open for all students across different faculties from sciences to humanities. As the very first step, the teaching starts by acknowledging, addressing, and challenging the negative associations and worries that people may have about evolutionary theory (e.g., immorality, determinism, eugenics). According to Wilson, when suspicions are discussed openly, for example, by assessing the wider historical perspective of utilizing theories as a tool for suppression, and by preliminarily discussing the idea that morality and social equality can also be approached from the perspective of modern evolutionary theory, students have the possibility to reflect on these associations by themselves and put them on hold. Students can shift their minds from an atmosphere of threat to an atmosphere of curiosity. After their worries are addressed, students can actually learn about the basic concepts of evolutionary theory (e.g., adaptation). After acquiring a broader understanding of basic evolutionary concepts, a teacher discusses the more specific intricacies of these concepts (e.g., not everything is adaptive). Throughout the course, students are treated as fellow scholars rather than passive receivers of information, for example, by inviting them to actively form predictions based on the new information they have learned, offering readings from primary research literature rather than textbooks, and asking them to explore their own topic from an evolutionary perspective. As a crucial component in this process, Wilson underlines the importance of the university's ability to act as a collaborative unit. Understanding of evolutionary mechanisms offers an example of a common language that defies the common field-specific specialization and seclusion in research and allows interdisciplinary collaboration. This notion is further supported by coordinating university-wide talks, which show in practice how researchers, not just in the sciences, but also in social and behavioral sciences and humanities, can work with different aspects of the same explanatory framework and form a coherent unit.

One indication of the effectiveness of Wilson's approach is that, based on the assessments conducted throughout the program, the factors that are commonly discussed as problematic or hampering an understanding of the theory of evolution (e.g., political or religious orientation), do not significantly affect the students' views or understanding about evolution in this program. What matters more than their personal worldviews is that they are approached as fellow scholars who are instructed about the basic concepts honestly and accurately.

In contrast to this, scientists and media often communicate about evolution by using machine and design metaphors, or intentional and teleological talk, for example, by referring to a personified nature or evolution that "designs" traits "for" some function (Padian; Pigliucci and Boudry; see also Fox Keller). Similarly, in the context of anthropogenic climate change, several scholars have suggested that as a tool to raise ecological awareness, one should use agentive reasoning in various ways, for example, to increase the sense of moral obligation toward a being who is external to nature (e.g., Markowitz and Shariff) or to elicit and strengthen the understanding of nature or the Earth as a being (e.g., Tam et al.; White). Interestingly, in practice, the effects on people's personal lifestyles and behavior have remained basically nonexistent (Veldman et al.). For instance, even if agentive views have effects on the ways people describe nature or their actions toward nature, they do not necessarily have an effect on their willingness to adopt conservational habits in practice (e.g., Kalland; Obadia).

Similar to the form of visual representations of scientific concepts—discussed more at length by Andrew Shtulman in this volume—metaphors anchor to the prior understanding that people have of a phenomena and can actively strengthen the misconceptions and interpretations that people form in reliance on their everyday reasoning. Although scientists and educators can use agentive language metaphorically (i.e., abandon agentive reasoning and explain evolution or anthropogenic climate change in reference to a physical mechanism if required), this does not mean that agentive metaphors or agentive reasoning serve as any kind of conceptual aid to the public. Quite the contrary, it is probable that, once being so in line with automatic intuitions about nature's purposes and design, these kinds of expressions just strengthen and further anchor ideas to preexisting cognitive biases and impede learning about nature (see Ganea et al.; see also Blancke, Tanghe, and Braeckman; and Tietge, this volume).

To conclude, in the context of the understanding of both evolution and anthropogenic climate change, it seems that instead of using agentive or design metaphors, scientists should think of ways to use expressions that aid physical-causal reasoning, for example, by referring to more familiar physical processes (Rudiak-Gould), given that understanding nonagentive or unintentional mechanisms is something where everyone needs cognitive help. In addition to enabling and paying more attention to accurate communication about the content of scientific theories and allowing individuals to properly reflect upon their automatic intuitions, in line with Wilson's example ("Evolution"), scientists could better focus on offering students, and also the public outside of universities, an example of the university as a unit that is able to work in an interdisciplinary manner, despite the scientific critique toward colleagues' ideas. In addition to being able to reflect the scientific conceptions by themselves, what seems to be at least as essential to decreasing people's suspiciousness and increasing openness to learning this kind of information is an understanding of the special nature of the culture of science associated with scientific theories, and welcoming people to take actively part in it.

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Chapter 8

Bridging the Gap: From Intuitive to Scientific Reasoning—The Case of Evolution

E. Margaret Evans

Abstract

This chapter notes that the use of intuitions to jump-start more sophisticated reasoning has been proposed for mathematics. The question addressed is whether core intuitions can also jump-start biological reasoning. Intuitive ideas can offer an immediate action plan that facilitates a rapid appraisal of the human mind or the natural world. Yet, there is a downside, such as a reliance on what may be inaccurate scientific judgments based on cognitive predispositions such as anthropomorphic or essentialist reasoning. Studies conducted with museum visitors are used to support the argument that specific cognitive predispositions can both help and hinder understanding. Further, this chapter claims that core intuitions can provide a series of stepping-stones, which, if navigated with care, may promote science learning.

The use of embodied intuitions to jump-start more sophisticated reasoning has been proposed for mathematics (Lakoff and Nunez). Can core intuitions also jump-start biological reasoning, in particular evolutionary reasoning? That is the question addressed in this chapter. Intuitive ideas can offer an immediate action plan (Kahneman), allowing us to make a rapid appraisal of the human mind or the natural world (e.g., a folk psychology or a folk biology: Wellman and Gelman). Yet, there is a downside, such as a reliance on what may be inaccurate scientific judgments (Stanovich et al.) based on cognitive predispositions such as teleological or essentialist biases (E. Evans, “Emergence” and “Cognitive”). Studies conducted with museum visitors will be used to support the argument that cognitive predispositions can both help and hinder biological reasoning, with a focus on evolutionary concepts. From the perspective of the science learner, it is important to identify when and how this happens.

Museum visitors provide an ideal population for such studies, as they are less likely than the general US population to reject evolution on ideological or religious grounds (E. Evans et al., “Conceptual Guide”). Further, it is possible to carry out a fairly rapid assessment of visitors’ reasoning before and after visits to exhibits on evolution; as well, the inclusion of different age groups makes it relatively easy to compare age- and experience-related changes in reasoning, simultaneously. Results from such studies can provide the basis for developmental learning trajectories. The main argument to be developed in this chapter is that to the extent that intuitive concepts provide a foundation for scientific reasoning (Duschl et al.), they should be incorporated into learning trajectories rather than treated as unwanted intrusions (e.g., Bishop and Anderson). Further, a developmental approach facilitates studies of the role that intuitive theories play in early science learning as well as their role as a default reasoning mode throughout the life span. A more nuanced understanding of intuitive reasoning modes would improve science learning more generally by providing a framework for closing the gap between intuitive and more reflective scientific reasoning (E. Evans et al., “Encountering”)

The focus of this chapter is on evolutionary concepts because they provide a compelling test case. While the historical (e.g., Quammen) and contemporary (e.g., Miller et al.) evidence suggests that evolutionary ideas are rejected on ideological and religious grounds, many have argued that specific cognitive predispositions play a key role in this rejection. As demonstrated in historical (Blancke et al.) and contemporary populations, such biases render the human mind resistant to ideas of evolutionary change while also making it easier to accept the idea that the origin of life on earth was miraculous (see E. Evans, “Conceptual Change” for a summary). Before describing those teleological (Kelemen; Shtulman and Calabi) and essentialist (Coley and Muratore; Gelman and Rhodes) biases theorized to make evolutionary ideas untenable (Mayr), I briefly review the extant literature on intuitive and reflective (scientific) reasoning and consider how the two might compete or cooperate when students study counterintuitive topics, such as evolution.

In Two Minds: Intuitive and Reflective Reasoning

The claim that there are "two minds in one brain" (J. Evans, *Thinking Twice*), the one intuitive and the other reflective, has been advanced by Jonathan Evans and Keith Stanovich, among others, with convergent evidence drawn from a variety of fields including neuroimaging, to support the basic concept (J. Evans and Stanovich). Following Jonathan Evans's *Thinking Twice,* in this chapter the terms *intuitive* and *reflective* will refer to what has been variously called system 1/system 2, type 1/type 2, and implicit/explicit processing. Linking this variety of proposals is a common thread. The intuitive brain is thought to be evolutionarily old while the reflective mind is more recent and may (arguably) be exclusively human; the former is a rapid parallel processor of implicit belief-based information often at a preconscious level (sensations and feelings), while the latter is a low capacity, effortful serial information processor of explicit information, often (but not always) at a conscious or meta-reflective level (J. Evans, *Thinking Twice*; J. Evans and Stanovich). Importantly, unlike type 2/reflective processing, type 1/intuitive processing is thought to be associative, operating independently of working memory and cognitive ability, while type 2 processing is rule based (J. Evans, "Dual-Process"; Stanovich et al., "Complexity").

Anyone familiar with the work on the emergence of children's theory of mind and executive function will recognize that according to any of these definitions the reflective mind is later developing, if assessed by children's increasing ability to exercise effortful control over their thought processes and to read the minds of others (e.g., Wellman; Zelazo). Thus, a clear developmental prediction is that intuitive processes, particularly intuitive theories, are most likely to influence the very young science learner. However, intuitive theories also provide a default for any age group under circumstances when they have to process information rapidly or are not explicitly instructed that they should be mindful of the problem (J. Evans and Stanovich).

Do intuitive and reflective reasoning processes compete with intuitions impeding an understanding of the issue at hand? The classic demonstration of such competition has been the case of the three-premise logical argument or syllogism (e.g., no A are B; some C are B; therefore, some A are not C) where the outcome is either logical but unbelievable or illogical and believable (J. Evans, *Thinking Twice* 114). In such studies, believable or unbelievable premises are substituted for A, B, or C. What tends to happen is that, with little reflection, participants will exhibit a belief bias and select the intuitively plausible but logically incorrect solution (J. Evans, *Thinking Twice*). In this case the intuitive and reflective minds appear to compete, delivering different solutions depending on the wording of the problem and whether or not the participant exercises effortful control over his or her intuitive response. These kinds of studies also demonstrate, however, that the reflective mind can suppress the output of the intuitive mind, providing it is given the time to do so and the motivation (J. Evans, *Thinking Twice*).

How might they cooperate? With the development of expertise in any field, it is the reflective mind that appears to oversee the initially effortful acquisition of novel skills; as the skills become routinized they are gradually subsumed under the direction of the intuitive mind. The classic example of this transfer of skill is driving. What is at first a long slow and mindful process gradually becomes a skilled activity that is performed speedily and intuitively with little access to the reflective mind (J. Evans, *Thinking Twice*). If, however, a novel problem arises, an icy road or an unexpected hazard, then the reflective mind swings into action and analyzes the problem, providing a new plan of action. What is important to note here is that in general the intuitive mind delivers a fast, effective, and accurate performance, particularly for routine tasks, even though it might provide an incorrect predetermined response to a novel hazard. In decision making the intuitive mind draws on past experience, a lifetime of repeated associations between diverse activities, behaviors, and outcomes. In contrast, the reflective mind analyzes the immediate present or the possible future, running explicit simulations (what-ifs) of possible outcomes and planning actions based on these simulations (J. Evans and Stanovich).

This necessarily brief description of the two-mind theory raises a host of questions regarding the way in which an understanding of the joint actions of intuitive and reflective processes might be used to help improve the delivery and understanding of scientific knowledge. In terms of skill development, Sun et al. ("Interaction") have suggested that implicit (procedural knowledge) and explicit (declarative) processes interact to produce learning; moreover, there are synergy effects. Although in the driving example just described the interaction would appear to be top-down, with the reflective mind jump-starting the process, Sun et al. present evidence supporting the argument that there are likely to be a variety of ways in which the two kinds of learning might interact. Sometimes making the learning process explicit hampers learning; in other cases, implicit and explicit learning appear to be independent processes with different time courses. To model the possibilities, Sun et al. present a neural network model with bottom-up intuitive processes as the driver, which accounts for different kinds of data, including cases in which learning occurs without conscious awareness. Two broad conclusions emphasized by these authors are the importance of modeling both implicit and explicit processes when studying learning and that bottom-up processes may be as important if not more so than top-down processes. Much of this research has focused on the learning of artificial grammars or similar problem sets where the influence of prior knowledge is not necessarily an issue, but what about problem sets where belief biases are viewed as a key concern, as is often the case for science understanding (Bloom and Weisberg)?

Initially, it would seem, the acquisition of scientific knowledge is likely to be effortful and slow as it is overseen by the reflective mind, particularly if it involves the suppression of intuitions that are at odds with scientific ideas. But once scientific reasoning becomes routinized and effortless, what happens to these core intuitions? Are they supplanted? As the evidence indicates that the belief biases of the intuitive mind never disappear, even if they are temporarily suppressed (J. Evans and Stanovich), perhaps a better approach would be to investigate how they are implicated in the learning process.

For evolutionary reasoning, the basic claim advanced by many researchers is that belief biases or cognitive predispositions compete with and impede scientific understanding (e.g., Kelemen; Gelman and Rhodes). If this is the case, one would predict that measures of belief bias would be negatively correlated with evolutionary reasoning. In the following sections, I demonstrate that this is not always the case, first for natural selection, and second, for common descent. In fact, I go further and argue that often such cognitive predispositions may jump-start scientific reasoning in a bottom-up process.

The Role of a “Restricted Teleology” in an Understanding of Natural Selection

Even if a particular intuition appears early and is then supplanted by scientific concepts, this does not mean that the intuition impedes scientific understanding. All this suggests is that it is a default reasoning mode brought to bear on a particular topic when more reflective reasoning modes cannot be exercised for lack of knowledge, time, access, or processing capacity. Essentially, this is the argument that I pursue in my discussion of the effects of teleological and essentialist reasoning (see Jarnefelt et al., and Jarnefelt, this volume, for a different perspective).

Of course, this does not mean that the same intuition may be helpful rather than a hindrance; such a claim requires a more nuanced argument.

One of the problems with research on intuitive reasoning is that the target intuitions are often underanalyzed or blended in such a way that it makes it difficult to decipher the precise roles they actually play in student learning. This is particularly a problem with the extensive research on the role of teleological reasoning in students' understanding of natural selection (E. Evans, "Conceptual Change"). Teleological reasoning is problematic because it implies purpose, progression, and intentional design, whereas natural selection exhibits none of these features—in fact the inverse is true. However, in studies investigating these effects, purpose and intention are routinely conflated. Students often reason that out of necessity an organism needs a particular trait in order to survive, in which case the trait satisfies an intrinsic purpose, called need-based reasoning. But, even if students lack knowledge of the mechanism by which traits evolve, it does not necessarily follow that they believe the trait is acquired through the intentional efforts of the organism, called desire- or want-based reasoning (E. Evans et al., "Encountering"). Or, even that an external agent such as God or mother nature designs the organism for a purpose (E. Evans, "Conceptual Change"). Fine-grained analyses of these reasoning modes suggest the existence of a "restricted teleology," whereby students may grasp the idea that an adaptation improves the survival of an organism without falling prey to anthropomorphic beliefs in which the organism or an external agent is able, like humans, to intentionally change the trait (E. Evans et al., "Encountering").

In investigations of this line of reasoning, study participants should be given the opportunity to endorse or reject each of these reasoning modes in separate closed-ended questions. Ideally, to gain further insight into their underlying reasoning, they should also be asked open-ended questions. Using this range of measures, Evans and her colleagues have conducted a number of studies among museum visitors of different ages and found that with age and expertise visitors increasingly distinguish between want- and need-based reasoning. Typically, younger school children conflate want- and need-based reasoning, endorsing both; thus, for this age-group, these modes are often significantly correlated (Legare et al.), as might be predicted from the research on young children's teleological reasoning (e.g., Kelemen). In contrast, older school children and adults often adopt a restricted teleological pattern, endorsing need-based reasoning while rejecting want-based reasoning (E. Evans et al., "Conceptual"; Spiegel et al.). For example, in a recent museum study (Horn et al.), 8- to 15-year-olds were presented with three diverse scenarios and asked to explain the adaptive changes that occurred over time in the target species. Unlike their younger counterparts, the 11- to 15-year-olds rejected anthropomorphic explanations (e.g., the lizards changed over time because "they don't like to get eaten") and endorsed need-based reasoning (e.g., "because the different kinds [of anoles] need to adapt to their different environments"). Critically, it is the latter pattern that is positively correlated with natural selection reasoning (Horn et al.; Spiegel et al.).

This overall pattern of results suggests that a restricted teleology could jump-start natural selection understanding by drawing attention to the necessity of the adaptation for survival while increasing visitors' sensitivity to natural mechanisms that do not involve the intentional actions of the organism. However, such studies do not provide evidence of a causal effect. Under what contexts might a restricted teleology be useful to the learner?

As the research team for a multicomponent exhibit on evolution, Evans and her colleagues investigated this phenomenon in more detail by incorporating these types of scaffolds into the development of a narrative-based exhibition called "Charlie and Kiwi's Evolutionary Adventure" (E. Evans et al., "Spiral"). This exhibit focused on the adventures of a young boy, Charlie, as he traveled back in time to discover why kiwis (including his stuffed kiwi) lacked the ability to fly and to find out what was so special about the ancestors of birds. In addition to a video theater experience, which conveyed the story of Charlie and Kiwi, the exhibition consisted of multiple components providing evidence of dinosaur-to-bird evolution. One of the challenges of an exhibition targeting school children was that the design team was inclined to use anthropomorphic language in the text, because it elicits interest and engages the young visitor. To assess how such language might affect understanding, the research team conducted several studies indicating that a restricted teleology might be a more effective cognitive tool.

In an initial qualitative assessment of children's understanding of natural selection, children were asked to recall the story of the Galapagos finches' survival, after viewing an exhibit on that topic. The following examples of children's language in their retelling provided converging evidence for the earlier findings (E. Evans et al., "Spiral" 49).

Interviewer: "Tell the story back to me."

Six-year-old: "The finch wanted a bigger beak" [example of want-based reasoning]

Nine-year-old: "You don't evolve because you want to . . . you evolve because you need to" [example of a restricted teleology]

As a follow-up to these qualitative studies, the research team ran an experiment in which children were randomly assigned to three conditions, in each of which children were told a story about bird evolution and then asked to recall the story. In one condition the story was presented using the language of natural selection, in a second condition, want-based reasoning, and in the third, need-based reasoning (Legare et al., "Anthropomorphizing"). On a variety of measures, the 5- to 7-year-olds were the most likely to use anthropomorphic reasoning and, overall, the anthropomorphic stories elicited the fewest scientific explanations. However, all children were more likely to use natural selection reasoning in their story recall if they had heard either the natural selection or the need-based stories, and this was especially true for the 9- to 12-year-olds.

This kind of evidence prompted the exhibit development team to ensure that the distinctions between want and need, in the form of a restricted teleology, were called out in the exhibit text and particularly in the video experience. For example, in Charlie's time travels he met up with his great-great-great-grandfather (who looked remarkably like Charles Darwin), and in one scene, while the two time-travelers viewed a nest of baby dinosaurs, some of which had feathers, the great-great-great-grandfather said: "Animals can't just grow feathers when they want to. They have to inherit them from their parents." Later, in another scene, when the old man was explaining why kiwis could not fly, he said: "No, but you must understand, Charlie: every bird has what it needs for where and how it lives. It's adapted to its environment" (E. Evans et al., "Spiral" figure 3.3). Note that in these examples, both intuitive and scientific explanations were incorporated into the text, thus merging top-down and bottom-up approaches into a single cognitive tool.

When the exhibition was complete, the research team ran a randomly assigned controlled study and found that the 5- to 7-year-olds who visited the target exhibit were much less likely than their peers who visited the control exhibit to endorse or use anthropomorphic language; additionally, the older children were more likely to use need-based reasoning and grasp the basics of natural selection than their peers who visited the control exhibit (E. Evans et al., "Spiral"). Such studies provide some evidence that when intuitive concepts are embedded in the narrative, be it in a curriculum or an exhibit, learners can transcend the intuitive and integrate more scientific modes of reasoning into their explanations. First, however, it is necessary for learners to distinguish between a restricted teleology, in which adaptive traits serve the intrinsic purpose of the organism, and a teleology that is intertwined with intentional reasoning.

The Role of an "Expanded Essentialism" in an Understanding of Common Descent

From the early days of research on cognitive biases that inhibit the understanding of biological concepts, essentialism has occupied a special niche in the minds of psychological and biological researchers alike (see E. Evans, "Conceptual Change"). Ernst Mayr, the foremost evolutionary biologist, noted that prior to Darwin "[Platonic] essentialism dominated the thinking of the western world to a degree that is still not fully appreciated by the historians of ideas" (38). What should replace it? According to Mayr it should be population thinking. Instead of the Platonic system of a natural world made up of types or kinds, each with their own fixed eidos or essence, Darwin ushered in population thinking with its emphasis on individuals, each one of which differed from its neighbor. Such variation is a key component of natural selection. While research indicates that an understanding of within-species variation is an important transitional concept paving the way to a deeper understanding of natural selection (Emmons and Kelemen; E. Evans et al., "Conceptual"), a focus on morphologically diverse species highlights a deeper problem. Students who might grasp the concept of within-species variation and, indeed, of natural selection, still essentialize kinds, failing to understand that all living kinds are related, with one individual differing to a greater or lesser degree from another in terms of molecular structure (Olson). Nowhere is this disconnect clearer than among creationists who, while believing that God placed each living kind on earth separately, may accept the concept of natural selection providing it is used to explain variation within a kind, such as dogs or fruit flies (E. Evans, "Conceptual Change"; E. Evans et al., "Conceptual").

Even members of the population who accept the idea of evolution agree that the more taxonomically diverse the species, the less likely they are to share an ancestor (Phillips et al.; Poling and Evans). In a study of undergraduates, some of whom strongly endorsed creationism and others of whom accepted evolution, all were more likely to agree that the more similar the species (e.g., rats, mice) the more likely it was they had an ancestor in common. The judgment for dissimilar species (e.g., sunflowers, bears) was that they were very unlikely to share an ancestor. Overall, though, the creationist and more evolutionist students did diverge, with the latter endorsing common ancestry at a significantly higher level (Poling and Evans). However, if they had embraced the logic of their belief systems, creationist students would have rejected any idea of common ancestry, while evolutionist students would have endorsed it strongly, regardless of the dissimilarity of the species depicted. These findings suggest that at an intuitive level, the idea that taxonomically diverse species are essentially different from one another is so ingrained in everyday reasoning that it can only be overcome at a reflective level. This psychological essentialism (Gelman and Rhodes) contrasts with philosophical or Platonic essentialism in that it is thought to be primarily an intuitive bias rather than one derived from cultural input. However, such essentialist biases are often reinforced by cultural input, not only as seen in creationist beliefs, which are reinforced by biblical texts, but also, paradoxically, by museums of natural history. Many if not most museum exhibits of prehistoric life display single iconic exemplars to represent a species or taxon, reinforcing typological reasoning (E. Evans et al., "Conceptual")

Modern cladistics may also reinforce these intuitions. As described by several researchers (e.g., Catley et al.; Shtulman, this volume), students and museum visitors alike are very likely to misinterpret biologists' trees of life, which display the evolutionary relationships of diverse species based on molecular or fossil evidence (or both). Static diagrams are necessarily limited in the number of taxa they can portray in a single graphic and they cannot convey the dynamic quality of the relationships. Moreover, visual groupings of limited numbers of taxa linked by a common ancestor reinforce the idea that taxonomically similar species share a common essence, which differs markedly from that of taxonomically dissimilar species. Even more egregiously, often there is a single image of an individual of the represented species, which again reinforces typological essentialist concepts. Overall, this line of research indicates that psychological essentialism is not only almost impossible to eliminate, but can also be inadvertently reinforced. If that is the case, perhaps a more radical approach is needed: embrace essentialism but expand it to include all living things. Recently, an interdisciplinary team of researchers have succeeded in doing just that, with a large digital touch table exhibiting a dynamic interactive tree of life (Block et al.)

One particular focus of this exhibit was the concept of relatedness, from the familiar notion of family relationships to the less familiar idea of evolutionary relationships. The dynamic visualization of 70,000 species in the interactive tree of life exhibit portrayed the idea that all living things on earth are related (Block et al.). Such a visualization extended the essentialist notion that each living kind has a unique, immutable essence by providing evidence of the common ancestry and shared traits of all living kinds, especially that of DNA. Visitors were encouraged to zoom through the entire tree of life or select images from a subset of 200 species representing key evolutionary groups and zoom to that species' location in the tree. For pairs of species, the visitor could also activate the "relate" function, to which the system responded by flying through the tree to the common ancestor of the two species. A key question was "how are humans and bananas related?" At the shared node, images and text could be activated, which depicted further information about the species, their ancestors, and their major shared traits, particularly that of DNA; the latter was represented throughout the exhibit by a glowing double helix.

In an experimental study carried out at two large museum sites, 250 8- to 15-year-olds were randomly assigned in pairs to one of four conditions consisting of two different versions of the tree of life interactive, a video on a similar topic, and a control condition, where there was no intervention; all the interventions were 10 minutes in length (Horn et al.). In the follow-up interviews, youth and their parents were asked about common ancestry, their interpretation of a tree-of-life graphic, their understanding and acceptance of evolutionary concepts, and related issues. The intuitions of participants in the control condition in response to questions about common ancestry can be seen in figure 8.1 (Phillips et al.). All

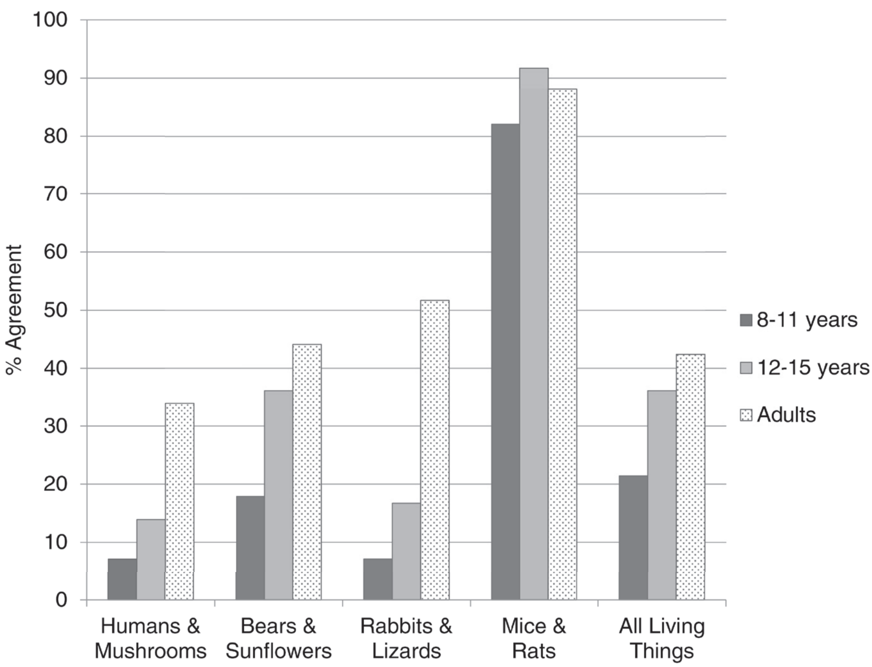

Figure 8.1 Common ancestry: percentage of museum visitors in each age group who agreed that the depicted groups of species share a common ancestor.

participants were asked whether particular groups of species shared an ancestor (five-point scale: 1 = disagree, 5 = agree); included in the final group of "all living things" were a beetle, a human, a flower, a bear, a reptile, and a kangaroo. Adults were significantly more likely than the youth to agree with common ancestry, but they, like the youth, were significantly more likely to agree that closely related species such as mice and rats had an ancestor in common (indicating that the question wording was easily understood).

These findings are compatible with the observation that the folk biological concept of living kinds, in which each kind possesses a unique and unchanging essence (E. Evans, "Emergence"; Gelman and Rhodes; Mayr; Samarapungavan and Wiers), emerges early and is widely held, even by educated museum visitors—the average adult in this study had a college degree. Overall, those visitors who agreed that diverse species, including humans, share a common ancestor were better informed regarding evolution in general and were more likely to feel that they were related to "all life on Earth" (Phillips et al.).

The key question for the study was whether the interventions themselves would have an effect. The answer was yes (Horn et al.). Youth who interacted with the touch table in either of the two interactive conditions were significantly more likely than their counterparts in the control or video conditions to endorse common ancestry, correctly interpret tree-of-life graphics, and use tree concepts in their responses to open-ended questions. Analyses of the dyads' interaction patterns indicated that the quality of their conversations and of their physical interaction with the exhibit was positively related to their endorsement of common ancestry, independently of demographic variables such as the youth's age and prior knowledge, parent educational level, and parent support for evolution. More specifically, youth who more often used genealogical terms in their conversation, such as "relate," and who referenced a greater number of diverse species were more likely to endorse common ancestry and reference shared traits such as DNA. Additionally, the more often the dyads activated key table functions, such as the relate function, the more likely they were to have these positive learning outcomes. Although the quality of the conversation and of the tabletop activations were related factors, they operated independently of each other in predicting the learning outcomes (Horn et al.).

In sum, an informal learning experience that encouraged pairs of youth to interact with a dynamic tree of life elicited genealogical concepts during the experience both in their conversation and in the exhibit activation, which, in turn, predicted a deeper understanding of Darwin's theory of common descent. This strongly suggests that these repeated interactions, leading inexorably to the observation that all living kinds have an ancestor in common, shifts the emphasis from the essence of morphologically similar species to the heretofore hidden essence of diverse living kinds, all life on earth—as indicated by shared DNA.

Practical Implications: Informal and Formal Learning Experiences in Science

Based on these two sets of findings, one on a restricted teleology and the other on an expanded essentialism, I argue that core intuitions can provide a series of stepping-stones (E. Evans, "Conceptual Change"; E. Evans et al., "Encountering"), which, if navigated with care, may scaffold science learning (see also Blancke, Tanghe, and Braeckman, this volume, for a similar argument). First, as demonstrated in these studies, what is required is a molecular approach to these intuitive patterns, dissecting out the differing concepts that have been subsumed under the broad categories of teleology and essentialism. Then, effective measures are needed to assess these concepts and embed them in new learning paradigms. Finally, it is necessary to devise pedagogical techniques that recruit the reflective mind, in this case children's emerging metacognitive skills (Wellman; Zelazo), to help achieve the transition from intuitive to scientific reasoning. These cognitive tools could be made accessible to purveyors of learning experiences from the classroom teacher to exhibit developers and, indeed, we were able to utilize them to a limited extent in effective museum exhibits (E. Evans et al., "Spiral"; Horn et al.). Nonetheless, currently this approach offers only a little more than a promissory note; what is needed is a deeper understanding of how these two minds, intuitive and reflective, can be integrated into a developmental learning program

Theoretical Implications: Dual Process Theory

"I shall argue that it is essential for the relatively neglected developmental story of dual processing to be worked out in any complete cognitive theory" (J. Evans, "Dual-Process" 87).

The clear (and obvious) predictions for the development of type 2 processing are supported by this research; the older the child or student, the more likely he or she is to use reflective learning processes and adopt scientific concepts, despite the impact of fairly powerful default reasoning modes provided by omnipresent cognitive biases. Importantly, as is clear from the responses of adults (see figure 8.1), such cognitive biases do not disappear. Type 2 processing does not supplant type 1 processing, moreover, they both coexist. In fact, there is substantive evidence to suggest that the use of both reasoning modes simultaneously is a typical feature of human cognition (E. Evans and Lane; E. Evans et al., "Engaging"; Legare et al., "Coexistence"). As discussed by both Jonathan Evans ("Dual-Process") and Stanovich the predictions for type 1 processing are less clear because essentially there is no such thing as a uniformly developing type 1 process (Stanovich et al., "Complexity"). Type 1 processes are manifest in a variety of forms, from early emerging cognitive biases, which may or may not be modular in origin (Wellman and Gelman), to automatized type 2 processes (Stanovich et al., "Complexity").

The examples described in this chapter are of particular cognitive biases or predispositions that are thought to be impediments to the acquisition of science concepts. There is a strong tendency in research communities to consider them biases that should be suppressed in order to acquire a veridical account of the world (e.g., Gelman and Rhodes; Kelemen; Shtulman and Calabi). Stanovich et al. ("Complexity") argue that the capacity to reason hypothetically, a reflective type 2 process, implies that it is not only necessary to clearly decouple the imagined and the veridical worlds, but also to override or inhibit type 1 processing. This is undoubtedly the case for many instances of controlled processing such as the execution of skilled behaviors.

In contrast, however, what I am suggesting here is that the acquisition of complex counterintuitive scientific material involves both type 1 and type 2 processing. The research described in this chapter indicates that with development, children are increasingly able to integrate the two types of reasoning processes, using type 2 processing to both modify intuitive biases, as in the case of teleological reasoning, and to amplify them, as in the case of essentialist reasoning. For this kind of learning to be effective, the reflective and intuitive systems must cooperate. These studies provide evidence of both top-down and bottom-up activations of implicit and explicit reasoning processes. Further, it seems obvious that a child or student cannot leapfrog directly from an intuition derived from a cognitive bias, such as anthropomorphic reasoning, to a scientifically acceptable grasp of a particular topic. What is needed instead is a series of stepping stones that guide the learner from an inaccurate to a more accurate scientific model—a developmental trajectory (E. Evans et al., "Encountering"). For this to be achieved, suppression of the intuitive concept is not sufficient; in fact, it might be counterproductive, as intuitive predispositions could well provide the student with an initial entrée into difficult scientific topics. In conclusion, this line of research indicates that the research community should rethink the role of intuitions in the acquisition of science concepts. As in mathematics, they may well jump-start the whole process.

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Author Profile

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Chapter 9

Missing Links: How Cladograms Reify Common Evolutionary Misconceptions

Andrew Shtulman

Abstract

Cladograms are tree-like structures devised by evolutionary biologists for conveying patterns of shared ancestry among biological kinds. These representations have become highly popular in science textbooks and science museums, yet most non-biologists have difficulty reading them. This chapter discusses how those difficulties stem from common misconceptions about evolution—misconceptions reinforced not only by what is included in cladograms but also by what is not included. Cladograms routinely omit information about extinction (depicting only the extant species within a taxonomic grouping), biodiversity (depicting only a subset of those species) and variation (depicting species with a single label), and these omissions, while irrelevant to how biologists understand cladograms, likely have cognitive consequences for how non-biologists understand them. The chapter concludes by considering other types of diagrams—circle diagrams, spiral diagrams, and bush diagrams—that depict patterns of shared ancestry with different graphing conventions and may thus be more appropriate than cladograms when their intended audience is non-biologists and their intended purpose is education.

A fundamental principle of modern biology is that all life is interconnected. Every organism on the planet is related to every other organism through common ancestry. This principle has implications for our understanding of all biological phenomena and is one that most biology educators hope to teach their students. Visual representations are a common means of teaching this principle, as visual representations can capture the depth and breadth of phylogenetic information more succinctly than words can. But the translation of phylogenetic information into visual representations has its challenges (Pennisi). One could design representations that highlight any number of phenomena: patterns of speciation and extinction across time, patterns of speciation and extinction across geography, changes in the complexity of existing lifeforms, or changes in the frequency of different anatomical plans. Historically, biologists have experimented with representations that highlight each of these phenomena (Gould, "Redrafting"), but one representation, in particular, has come to dominate modern biological science: the cladogram.

Cladograms highlight a single property of life—common ancestry—and they do so through a series of branching relations. Given a collection of *taxa,* or taxonomic groupings (e.g., species, genus, family, or order), the pair of taxa that share a common ancestor more recently than any other pair are connected with lines that converge at a node. This node represents their common ancestor. The pair is then connected to every other taxa via the same logic: taxa that share more recent ancestors are connected prior to those that share more distant ancestors until all taxa are interconnected. Each new connection yields a new node, with deeper nodes signifying ancestors that are more distant (time-wise) and more widespread (descent-wise). As an illustration, consider the cladogram displayed in figure 9.1, which depicts the ancestral relations among apes. This cladogram indicates that humans and chimpanzees share a more recent ancestor than do any other pair of apes. Humans and chimpanzees, in turn, share a more recent ancestor with gorillas than they do with orangutans, and humans, chimpanzees, and gorillas share a more recent ancestor with orangutans than they do with gibbons.

Within the scientific community, cladograms have become a mainstay of phylogenetic analysis for a number of reasons, the foremost being that technological advances in gene sequencing have made it possible to discern shared ancestry at a molecular level. But one need know nothing about the genetic basis of cladograms to glean profound insights from them. Cladograms can greatly alter commonsense notions of when and how different types of lifeforms emerged. By appearance alone, we might assume that manatees are closely related to dolphins and that elephants are closely related to cows, but a cladogram that includes all four would tell us that manatees are actually more closely related to elephants and that dolphins are more closely related to cows. Likewise, we might assume

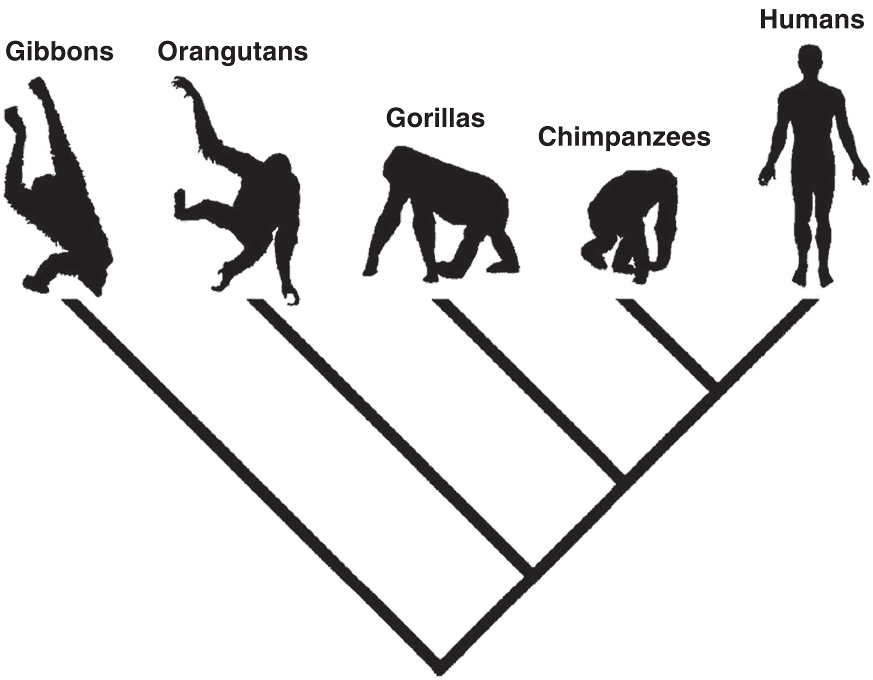

Figure 9.1 Cladogram (in the form of a ladder diagram) depicting the ancestral relations among five modern primates, adapted from Gregory, "Understanding Evolutionary Trees."

that two creatures with eyes are more closely related to one another than either is to a creature without eyes, yet a cladogram that includes both eyed and non-eyed creatures would tell us that eyes emerged independently across several lineages and that having eyes is not as reliable an indicator of shared ancestry as certain other traits, like having lungs or having a spine.

For their simplicity, cladograms are surprisingly powerful tools for decoding the mysteries of diverse morphology, and, as such, they have spread beyond the scientific domain into the public domain, becoming a stock representation in science textbooks (Catley and Novick) and science museums (MacDonald and Wiley). Recent research, however, suggests that most non-biologists have difficulty understanding cladograms (Gregory, "Understanding Evolutionary Trees"). In this chapter, I argue that those difficulties stem from common misconceptions about evolution (Shtulman; Shtulman and Calabi, "Cognitive Constraints") and that individuals who hold such misconceptions are not simply confused by cladograms but actively misinterpret them. In particular, I argue that misconceptions about evolution influence not only our understanding of the elements contained within a cladogram—its lines, nodes, branches, and tips—but also our understanding of the elements missing from a cladogram. Three such elements, routinely omitted from cladograms, are those that pertain to extinction (cladograms typically depict only the extant species within a *clade,* or group of organisms united by a particular common ancestor), biodiversity (cladograms typically depict only a subset of extant species within a clade), and variation (cladograms depict species as unitary entities and provide no representation of the variation within a species). Information about extinction, biodiversity, and variation is irrelevant to how biologists use cladograms—to depict a hypothesized sequence of speciation events among a predefined set of species—but omitting that information may paint a skewed picture of evolution for non-biologists.

In short, I argue that, when viewing cladograms, non-biologists interpret an absence of evidence—evidence regarding extinction, biodiversity, and variation—as evidence of absence. Further, I argue that cladograms may need to be replaced with other types of representations, such as circle diagrams (Novick and Catley), spiral diagrams (Ricou and Pollock), or bush diagrams (Gould, "Bushes"), when their intended audience is non-biologists and their intended purpose is education.

Common Misconceptions about Evolution

The eighteenth-century biologist Jean-Baptiste Lamarck proposed a theory of evolution in which organisms acquire adaptive traits throughout their lives and then pass those traits to their offspring. Students in today's biology classrooms are easily dissuaded of the idea that acquired traits are inherited (Springer and Keil); amputees do not, after all, give birth to limbless babies. But they are less easily dissuaded of the broader idea, implicit in Lamarck's theory, that individuals evolve rather than populations. In other words, non-biologists tend to view evolution as the uniform transformation of all individuals within a species rather than the selective survival and reproduction of just a few.

At least two factors are responsible for this misconception. One factor is our tendency to essentialize species or assume that species possess an underlying nature (or "essence"), which determines their outwardly observable appearance and behavior (Gelman; Medin and Atran; Solomon and Zaitchik). This bias serves us well when reasoning about the development of individual organisms, but serves us poorly when reasoning about the evolution of entire species, because it causes us to undervalue the variation within a species. And without variation, there can be no selection. Another factor is our tendency to perceive nature as a caring and benevolent place—a peaceable kingdom rather than a Malthusian struggle (Ozkan et al.; Zimmerman and Cuddington). We underestimate the extent to which organisms compete for resources, especially within the same species. Consequently, we fail to appreciate the transformative power of selection, that is, the transformative power of dying without leaving any offspring. We gravitate instead towards the more optimistic belief that organisms will somehow acquire the traits they need to acquire in order to survive, with selection playing no role in this process (for a review, see Gregory, "Understanding Natural Selection"). These misconceptions are highly coherent (Shtulman and Calabi, "Cognitive Constraints") and highly robust (Shtulman and Calabi, "Tuition vs. Intuition"). In fact, they resemble theories of evolution proposed prior to Darwin in the history of science (Shtulman).

Misconceptions about the mechanisms of evolution give rise to misconceptions about the outcomes of evolution, that is, misconceptions about the origin of new species (speciation) and the demise of old species (extinction). With respect to speciation, those who hold an essentialist view of evolution have difficulty conceiving of speciation as the splitting of one population into two, because all members of the original population are assumed to be united by a common and enduring essence. Consequently, they prefer to view speciation as the holistic metamorphosis of one population into another. This preference for linear evolution ("anagensis") over branching evolution ("cladogenesis") leads to the misconception that morphologically similar species are related through direct descent rather than common descent—for example, that chimpanzees are the ancestors of humans rather than their cousins (Catley et al.). Furthermore, most non-biologists deny that morphologically dissimilar species, like salamanders and sparrows or bees and brontosauruses, are related at all (Poling and Evans, "Religious Belief"; Shtulman).

With respect to extinction, the belief that organisms acquire the traits they need to acquire gives rise to the misconception that extinction is rare, occurring at the hands of catastrophic disasters, like earthquakes or floods, but not at the hands of more mundane forces, like predation or disease. Extinction, from a selection-based view of evolution, is just selection writ large, but it cannot be such from an essentialist view because essentialist views make no room for selection. Whatever process is responsible for adapting a species to its environment should also ensure that the species will not go extinct. Consequently, those who hold essentialist views of evolution greatly underestimate the frequency of extinction over time (Shtulman) and the ubiquity of extinction across species (Poling and Evans, "Are Dinosaurs the Rule").

Common Misinterpretations of Cladograms

The fact that most non-biologists hold deep-seated misconceptions about speciation and extinction does not bode well for their interpretation of cladograms, which depict patterns of speciation and extinction across clades. Indeed, several studies have found that non-biologists have difficulty reading cladograms (Catley et al.; Gregory, "Understanding Evolutionary Trees"; Halverson et al.; Novick et al., "Linear Versus Branching"; Phillips et al.; Shtulman and Checa) and constructing cladograms (Meir et al.; Novick and Catley; Novick et al., "Characters are Key"). These difficulties cluster into two general categories.

First, most non-biologists misinterpret the ordering of the taxa along the tips of the cladogram, reading information into the ordering that is not supported by the cladogram's branching relations. The ordering of taxa in a cladogram is, to a large extent, arbitrary. While taxa that share a most recent common ancestor must be adjacent (e.g., chimpanzees and humans in figure 9.1), their ordering relative to one another can be changed (e.g., chimpanzees can appear either to the left of humans or to their right), as can the ordering of entire clades (e.g., gorillas can appear either to the left of the human/chimpanzee clade or to its right). Any two clades can be rotated around the node that connects them, resulting in 2^n possible orders for every node in the graph. The five species depicted in figure 9.1, for example, could be presented in 16 (or 2^4) possible orders, including the following three:

Gibbons, (Orangutans, ((Chimpanzees, Humans), Gorillas))
Gibbons, (((Humans, Chimpanzees), Gorillas), Orangutans)
(((Chimpanzees, Humans), Gorillas), Orangutans), Gibbons

These rotations are possible because a branch between two taxa indicates only that those taxa share a more immediate ancestor with each other than they do with any other taxa, in the same way that two siblings share a more immediate ancestor with each other than they do with any of their cousins. Nevertheless, most non-biologists assume that taxa on the left are more ancient or more primitive than those on the right—or, in a vertically arrayed cladogram, that taxa at the bottom are more ancient or more primitive than those at the top. A corollary of this assumption is that the further apart two taxa appear along a cladogram's tips, the more distantly they are related. Figure 9.1, for instance, would be commonly misinterpreted as indicating that gibbons are the most ancient/primitive of the five taxa and that gibbons are more closely related to orangutans than they are to humans. In reality, this cladogram indicates that gibbons have evolved independently from other apes for as long as other apes have evolved independently from gibbons, and gibbons are no more closely related to orangutans than they are to humans.

Second, most non-biologists misinterpret the linear elements of a cladogram, assuming that the length of the line connecting a taxon to its nearest node conveys information about that taxon's evolutionary history when, in fact, it does not. The lengths of a cladogram's lines are essentially arbitrary, as are their orientation and their curvature. Moreover, the number of nodes contained on any given line provides no information about how closely the taxon at its tip is related to any other taxon. Gibbons and humans, for instance, are as closely related to one another as gibbons and gorillas despite the fact that, in figure 9.1, there are four nodes on the path from gibbons to humans but only three on the path from gibbons to gorillas. The number of nodes is merely a byproduct of the number of taxa included in the cladogram. Drop chimpanzees from the cladogram and the number of nodes between gibbons and humans drops from four to three. Nevertheless, most non-biologists read meaning into how long a line is (the longer the line, the older the taxon) and how many nodes appear on its surface (the more nodes, the more distantly the taxon is related to other taxa in the clade). These misinterpretations are not unreasonable; how long a line is and how many nodes appear on its surface bear meaningful information in other types of diagrams (e.g., road maps, line graphs, flow charts, blueprints).

Further complicating matters, many depictions of shared ancestry designed for public consumption include scientifically questionable elements. Cladograms, by definition, are a representation of cladogenesis, or branching evolution, yet most cladograms in textbooks and science museums include representations of anagenesis, or linear evolution as well (Catley and Novick; MacDonald and Wiley; MacFadden et al.). That is, the nodes in these diagrams are labeled with extinct species, implying that those species gave rise to the extant species along the diagrams' tips. Empirically, such representations are suspect because biologists cannot ascertain whether an extinct species is the ancestor of an extant species or its cousin, and the latter inference is several times more likely (given the ubiquity of extinction). Other problematic features common to cladograms in science textbooks and science museums include varying the thickness of its branches without explanation, varying the endpoints of its branches without explanation, segregating "higher" taxa from "lower" taxa, and placing humans on the top-most branch of a vertically arrayed cladogram or the right-most branch of a horizontally arrayed cladogram (Catley and Novick; MacDonald and Wiley; Torrens and Barahona).

Potential Misinterpretation of Information Missing from Cladograms

To summarize thus far, most non-biologists hold essentialist views of evolution that make branching speciation a conceptual quandary, so they ignore the branching relations in a cladogram and attend primarily to its non-informative elements: the ordering of its tips, the lengths of its lines, and the frequency of its nodes. Ignoring the branching relations in a cladogram is highly problematic, but it is not the only problem that may arise from an essentialist view. Cladograms omit several types of information that, from a biologist's point of view, are innocuous forms of simplification but, from a non-biologist's point of view, may be seen as veridical representations of evolutionary change. Below I discuss three such omissions, noting how those omissions may reify and reinforce the essentialist misconceptions reviewed above.

The Omission of Extinction

Cladograms have come to dominate the biological sciences mainly because they can be constructed using highly objective information: similarities in genetic structure (Pennisi). It is possible to build cladograms from morphological information, but such information is less reliable, as it is rarely clear from visual inspection alone whether a trait observed in two taxa was inherited from a common ancestor (a *homologous* trait) or was derived separately in response to similar selection pressures on organisms whose common ancestor did not possess that trait (an *analogous* trait). This situation poses problems for including extinct taxa in modern cladograms because our knowledge of extinct taxa is primarily morphological in nature; fossils contain no living tissue for genetic analysis. As a result, when extinct taxa are included in textbook diagrams or museum diagrams, they tend to be placed in the branches of the diagram rather than at its tips (Catley and Novick; MacFadden et al.). Among genuinely cladistic representations of shared ancestry in textbooks and museums, extinct taxa are rare (MacDonald and Wiley).

This absence of extinct taxa potentially reinforces the misconception, noted above, that extinction is uncommon and that extinction affects only certain types of species (Jarnefelt, this volume; Poling and Evans, "Are Dinosaurs the Rule"; Shtulman). The reality is that over 99.9% of the species that once existed are now extinct (Mayr), and cladograms, by representing the 0.1% of species that happen to have survived to the present (and a small subset of the 0.1% at that), present a skewed picture of the outcome of evolutionary change. Perhaps more problematic, the blind and messy process of mutation-plus-selection is represented as a series of straight and orderly lines. The historical record is wiped clean of all false starts and blind paths, leaving only the "successful" lineages still present today. While cladograms are certainly an improvement over anagenetic representations of evolutionary change, they still vastly underrepresent the frequency of cladogenesis in that every instance of cladogenesis represented in the tree was likely accompanied by dozens of instances not represented.

This speculation—that non-biologists are unclear on how extinction is (and is not) represented in cladograms—is supported by a study of how visitors to the Los Angeles Natural History Museum interpret one of the museum's cladograms (Shtulman and Checa). Participants completed a series activities using a cladogram that depicted all 19 orders of mammals. In one activity, participants decided whether an extinct, pig-like creature—an "entelodont"—could be placed within the cladogram and, if so, where. Virtually all participants (96%) agreed that the entelodont could be placed within the cladogram, but only a minority (39%) discerned that it should be located on a branch within the ungulate clade. Most participants thought the entelodont should be located either at the bottom of the cladogram, near its root (45%), or on a separate branch altogether (12%). Thus, the modal response was to treat the entelodont either as an ancestor to all mammals or as an isolated lineage related to no mammals.

The Omission of Biodiversity

Just as extinct taxa tend to be omitted from cladograms, so are many extant species within the depicted clades. Such omissions date back to one of the very first depictions of the interconnectedness of life: Ernst Haeckel's (1866) "tree of life," covering everything from insects to mammals. While Haeckel devoted an entire layer of branches to the four thousand species of mammals—conspicuously depicted at the top of the tree, with humans in the center—he devoted only a single branch to the million species of insects (Gould, "Redrafting the Tree of Life"). Another example of the omission of extant species can be seen in figure 9.1. Only one tip in this cladogram represents a unitary species: the tip labeled "humans." The tips labeled "orangutans," "gorillas," and "chimpanzees" represent two species each—Bornean and Sumatran orangutans, eastern and western gorillas, common and pygmy chimpanzees—and the tip labeled "gibbons" represents 15 different species. These examples, among others (see Gould, "Redrafting the Tree of Life"), suggest that the less salient a taxon is in our folk biology, the fewer tips we devote to that taxon in our cladograms.

Obviously, not all species can be represented in a single cladogram; a cladogram containing 3000 species, designed by David Hillis and his colleagues at the University of Texas at Austin, is legible only when enlarged to a size of 1.5

meters or more (Pennisi), and 3000 species is less than 0.1% of the total number of known species. But all species within a clade can be represented if the clade chosen for depiction is sufficiently small. For instance, figure 9.1 could be redesigned such that gibbons are dropped from the cladogram and the remaining clades could be expanded to include all known species. Doing so would not only highlight the diversity among the great apes but would also lessen the impression that those species are ordered from least complex to most complex, as is implied by the current ordering.

An additional problem created by compressing a diverse clade into a single tip is that the particular species chosen to label the clade, as a whole, likely influences our interpretation of its relation to other clades in the diagram. Consider, for instance, the fact that the genus *Pan* is almost always represented by *Pan troglodytes,* the common chimpanzee, rather than *Pan paniscus,* the pygmy chimpanzee or "bonobo." These two species, while roughly similar in morphology, differ widely in behavior. Whereas common chimpanzees are hostile, patriarchal, and meat eating, pygmy chimpanzees are docile, matriarchal, and vegetarian. We humans are as closely related to pygmy chimpanzees as we are to common chimpanzees, yet our relation to common chimpanzees undoubtedly looms larger in our minds given how frequently that relation is depicted in primate cladograms.

There is no research, to my knowledge, supporting the speculation that the type of biodiversity represented in a cladogram influences how we interpret that cladogram. There is, however, ample research demonstrating that non-biologists underestimate biodiversity in general. For instance, US undergraduates conceptualize trees and fish as basic-level categories—categories that are optimally cohesive in terms of the number of features shared by all category members—even though, from a biological point of view, "tree" and "fish" should function as superordinate categories given the great diversity of organisms they cover (Rosch et al.). Likewise, in a survey of US undergraduates' tree knowledge, over 90% reported familiarity with Cedar, Hickory, Maple, and Spruce trees, but fewer than half reported any familiarity with Alder, Buckeye, Hawthorn, or Sweetgum trees, even though many had encountered those trees daily on their campus (Coley et al.). And use of tree terms, flower terms, bird terms, and fish terms in English-language documents has dropped precipitously from the nineteenth century to the twentieth, concurrent with a precipitous increase in artifact terms (Wolff et al.). These data suggest that we systematically underestimate the biodiversity around us and are therefore unlikely to infer the biodiversity missing from a cladogram.

The Omission of Variation

As noted above, non-biologists tend to view variation between species as pervasive and adaptive but variation within species as minimal and nonadaptive—a byproduct of essentialism. Such notions influence a variety of cognitive processes, including memory (Legare et al.), categorization (Nettle), induction (Shtulman and Schulz), and explanation (Opfer et al.). Cladograms do not help dissuade these notions. If anything, they reinforce them by representing diverse populations with a single image or a single label. The only variation depicted in a cladogram is variation across species, which, depending on the species chosen for inclusion, can be quite dramatic.

Admittedly, the unit of analysis in a cladogram is some form of higher-order taxon (e.g., species, genus, family, order) and any attempt to depict variation within a population would detract from the information cladograms are designed to display (i.e., the ancestral relations among those populations). Nevertheless, the omissions described above—omission of extinct taxa and omission of several extant taxa within the same clade—likely exacerbate essentialist interpretations of biological kinds in that taxa are regularly isolated from the continuum of variation from which they came.

Figure 9.1, for instance, portrays only five taxa when, in reality, those taxa cover 22 different species. Humans' place among the apes would appear much less distinct if all 22 species were explicitly represented (and if the branches of the cladogram were rotated so that humans appeared somewhere in the middle of that continuum). Humans' place among the apes would also appear less distinct if extinct apes were intermixed with the extant ones. Indeed, cladograms depicting humans among a sea of extinct hominids, like the cladogram on display in the Hall of Human Origins at the American Museum of Natural History (Novick et al., "Depicting the Tree of Life"), likely engender less essentialist views of humankind than those that depict humans among organisms with minimal resemblance to humans (e.g., fish, turtles, birds, flowers), though future research is needed to verify this speculation.

Alternative Representations

The only cladogram we have considered thus far is figure 9.1, which is a particular type of cladogram: a ladder diagram. Cladograms can also be constructed as "trees," as shown in figure 9.2 (Catley and Novick). The omissions described above are not fatal flaws of tree diagrams or ladder diagrams. Both could be redesigned to include the omitted information. Still, tree and ladder diagrams may

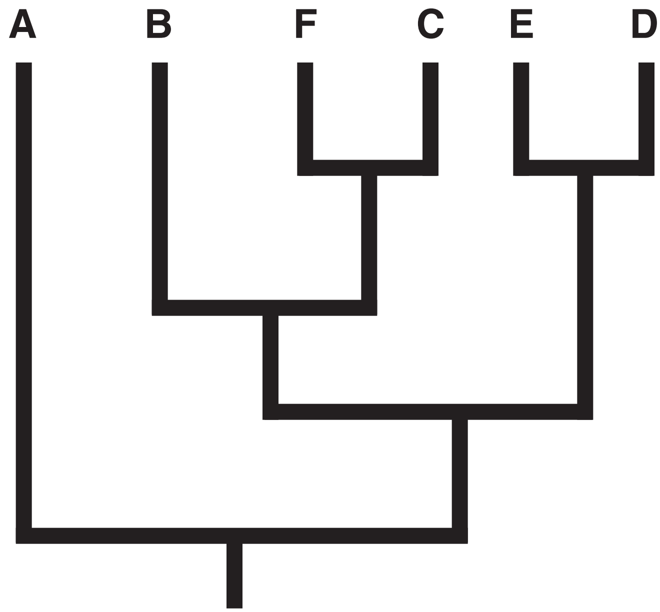

Figure 9.2 Tree diagram depicting the ancestral relations among six hypothetical taxa, adapted from Gregory, "Understanding Evolutionary Trees."

not be the best representation of information about extinction or biodiversity. Other types of representations may be better suited for those purposes. Tree and ladder diagrams may play an essential role in modern biology (Novick and Catley), but their value as a scientific tool does not justify their use in the public domain. It is an empirical question which representations of phylogenetic information are best suited for conveying that information to a lay audience.

Below, I outline three hypotheses relevant to this question: (1) circle diagrams are better suited than tree or ladder diagrams for conveying information about common ancestry but are not well suited for conveying information about extinction or biodiversity; (2) spiral diagrams are better suited than tree or ladder diagrams for conveying information about biodiversity but are not well suited for conveying information about common ancestry or extinction; and (3) bush diagrams are better suited than tree or ladder diagrams for conveying information about extinction but are not well suited for conveying information about common ancestry or biodiversity. The first of these hypotheses has been (partially) tested and supported, but the remaining two have not. All three, however, are motivated by what we currently know about how people understand evolution and how people read cladograms, outlined above. And they are proposed in the spirit of what other authors in this volume have argued: that intuition can facilitate scientific reasoning, rather than obstruct it, if the right intuitions are accessed and accessed in the right ways (Blancke, Tanghe, and Braeckman, this volume; Evans, this volume).

Circle Diagrams

In an analysis of the visual representations contained in 31 biology textbooks, Catley and Novick, in "Seeing the Wood," found that cladograms are most typically portrayed as ladders (figure 9.1). The second most common format is that of a tree (figure 9.2). Trees and ladders are informationally equivalent, differing only in whether the lines connecting taxa meet at an angle or at a rectilinear juncture, but trees are easier to read because the clades are more visually distinct, which makes the nested relations among those clades easier to discern (Novick and Catley). A third type of diagram—the circle diagram, depicted in figure 9.3—makes the nested relations among clades even more salient. A circle diagram differs from a tree or ladder diagram in that shared ancestry is conveyed with concentric circles rather than nested branches. It is essentially a bird's eye view of a tree or ladder diagram—in this case, a bird's eye view of figure 9.2—in that the branches of such diagrams are collapsed to a single dimension. Doing so is conceptually ideal given that the vertical dimension of a tree or ladder diagram conveys no intrinsic meaning. Moreover, circles are a more natural representation of groups than are branches, as all members of the group can be encapsulated in one spatially continuous figure.

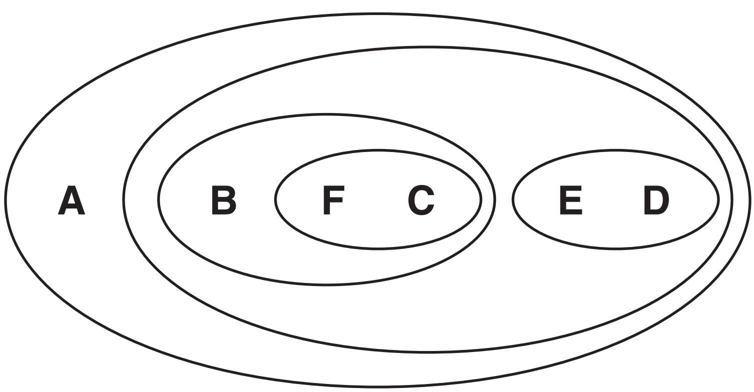

Figure 9.3 Circle diagram of the same taxa displayed in figure 9.2.

Novick and Catley explicitly compared the affordances of ladder, tree, and circle diagrams by asking two groups of college undergraduates—psychology majors and biology majors—to translate the phylogenetic information presented in one format (e.g., a tree diagram) into another (e.g., a ladder diagram) ("Understanding Phylogenies"). They found that participants were most accurate at translating phylogenetic information from circle diagrams. In fact, presenting phylogenetic information in a circle diagram nullified the effect of participants' background knowledge, with psychology majors performing nearly as accurately as biology majors (85% accuracy vs. 95% accuracy, respectively). Presenting the information in a tree or ladder diagram, on the other hand, decreased accuracy relative to the circle-diagram condition, by 15–50% for biology majors and by 50–75% for psychology majors. Circle diagrams allowed participants to glean information about common ancestry that was otherwise opaque in the form of trees or ladders.

That said, it's not clear that circle diagrams are an ideal format for presenting information about extinction or biodiversity for the simple reason that they do not expand well. With each new clade comes a new circle, and each circle must surround, or be surrounded by, other circles. The net effect can be an overwhelming number of boundaries. These boundaries direct attention effectively when few in number but may attract attention, as focal objects themselves, when more numerous. To represent the predominance of extinct taxa or the diversity of extant taxa within a clade, an alternate format is probably desirable.

Spiral Diagrams

Figure 9.4 depicts the same information as depicted by figure 9.2 (and figure 9.3) but in a qualitatively different format: a spiral. Spiral diagrams are most frequently used to illustrate the interconnectedness of all life on earth, from bacteria to fungi to animals to plants (Ricou and Pollock), but they could just as easily be used to represent a more select group of taxa, like the primates depicted in figure 9.1.

Spiral diagrams may be an ideal format for depicting the ancestral relations among a single family or order for several reasons. First, spiral diagrams are more efficient in their allocation of tips to branches. More species can be packed into a spiral diagram than into a similarly sized tree or ladder diagram because the tips are arrayed in a circle, thereby making use of both horizontal and vertical dimensions of the space. Second, spiral diagrams lack the directionality or polarity inherent in tree and ladder diagrams. There is no top-most branch or right-most branch that might be construed as the "pinnacle" taxon (as many non-biologists

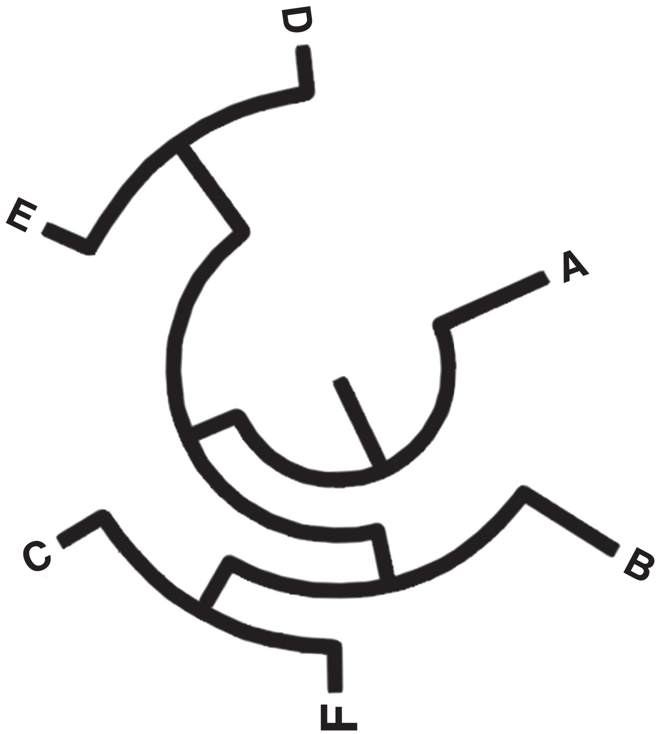

Figure 9.4 Spiral diagram of the same taxa displayed in figure 9.2, adapted from Gregory, "Understanding Evolutionary Trees."

are prone to construe humans; see Guillo, this volume). Third, spiral diagrams convey an intrinsic sense of proportionality by virtue of their pie-like structure. The proportion of space occupied by one clade (e.g., the great apes) relative to another clade (e.g., the lesser apes) is more apparent in a spiral diagram than in a tree or ladder diagram and might thus convey a more veridical representation of diversity within and across clades.

The main drawback to using a spiral diagram is that precise information about common ancestry is difficult to discern from a spiral diagram, particularly for spirals that contain hundreds—or thousands—of species (Novick et al., "Depicting the Tree of Life"). Spiral diagrams are also ill-suited for depicting extinct taxa for the same reasons that tree and ladder diagrams are: all taxa are displayed along a single line (or curve, in this case), and it is thus difficult to differentiate extinct taxa from extant taxa unless they are denoted with different fonts or different colors. While one could potentially vary the placement of the tips in a tree diagram to indicate which taxa are extant and which are extinct, this strategy would be difficult to implement in a spiral diagram without breaking the continuity of the spiral. Spiral diagrams may thus be best suited for representing information about the density of taxonomically similar lifeforms or the interconnectedness of different types of life.

Bush Diagrams

None of the diagrams reviewed thus far are ideal for representing extinct taxa because they feature all taxa along a single line (or curve) with no inherent markers for distinguishing extant taxa from extinct taxa. One way to circumvent this problem, in a tree diagram or ladder diagram, would be to place extinct taxa within its branches rather than at its tips, but doing so would render the diagram non-cladistic and potentially misleading, as noted above. An alternative solution would be to relax the constraint that all branches need to terminate along a single line or the constraint that all branches need to be oriented in the same direction (Gould, "Bushes"). The result is a bush diagram of the kind displayed in figure 9.5. Figure 9.5 conveys the same information as that conveyed by figures 9.2, 9.3, and 9.4, but in a less orderly manner, consistent with the less-than-orderly nature of evolutionary change itself. Indeed, what is most salient in a bush diagram is not the ordering of the taxa but the branches connecting taxa to nodes. Its nodes take visual precedence over its tips. And in such a diagram, there is no expectation that the tips represent only extant taxa because the tips are not arrayed along a line implicitly interpreted as "present day."

The bush diagram in figure 9.5 was co-opted from one the most iconic sketches of evolutionary change drawn by Darwin in 1837. This sketch, appearing in his *Notebook B,* was annotated with the conjecture, "to have many species in same genus . . . requires extinction." Darwin underlined "requires" to emphasize the necessity of extinction to speciation. He recognized that species do not just metamorphosize from lesser-adapted forms to better-adapted forms. They fractionate, splitting into a diversity of forms, and that diversity is then selectively winnowed. Every modern species represents a small fraction of the innumerable lifeforms that once existed—lifeforms whose fate was extinction rather than propagation.

Thus, the purpose of Darwin's best-known visual representation of evolutionary change was to make salient the relation between extant species and extinct species. Darwin's diagram is well suited for this purpose because the "stubbiness" of its terminal branches is consistent with the brevity of the lineages they represent. Indeed, those branches need not be labeled, though they certainly could be

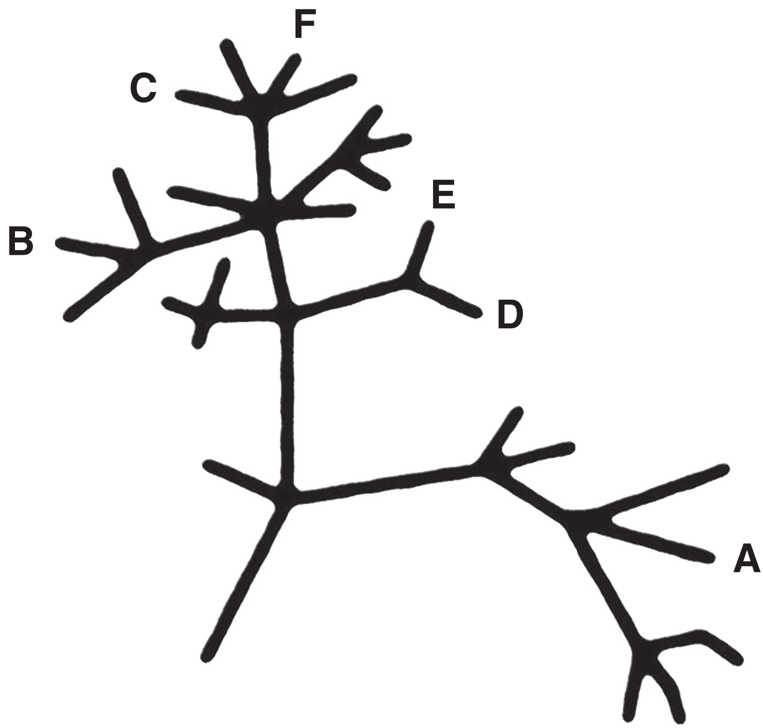

Figure 9.5 Bush diagram of the same taxa displayed in figure 9.2, adapted from Darwin, *Notebook B*.

in cases where biologists know a fair amount about the extinct taxa of interest (e.g., extinct horses or extinct hominids). Of course, a diagram that emphasizes nodes over tips is not an ideal diagram for reading the relations among tips (i.e., for reading information about common ancestry), nor is it ideal for representing the biodiversity among extant taxa insofar that the stubbiness of its tips establishes the expectation that those lineages have been pruned from the tree.

Conclusion

Misconceptions about evolution can lead people to misinterpret cladograms. To date, much research has been done on misinterpretations of a cladogram's core elements—its lines, tips, nodes, and branches—but little research has been done on misinterpretations of the elements missing from a cladogram. Here, I have argued that omission of extinct taxa from cladograms reifies the common misconception that extinction is an atypical outcome of evolutionary change, that omission of within-clade biodiversity reifies the common misconception that extant species are largely unrelated to one another, and omission of variation (in general) reifies the common misconception that between-group variation is more common than within-group variation, but these hypotheses need empirical verification. I have also argued that circle diagrams, spiral diagrams, and bush diagrams do a better job of representing common ancestry, biodiversity, and extinction, respectively, than do ladder diagrams and tree diagrams, but these hypotheses need verification as well.

Regardless of whether the specific claims sketched above will survive empirical scrutiny, the more general claim that no one graph fits all instructional purposes has been born out in decades of research on graph comprehension and graph construction (for a review, see Anderson et al.). Different graphing conventions have proven effective for representing different types of information, and this conclusion will likely hold for evolutionary diagrams as well. Thus, graphic designers charged with illustrating phylogenetic information in science textbooks or science museums may need to reconsider whether a tree diagram or a ladder diagram is the best diagram for the job. While these diagrams are powerful tools in the hands of biologists, they may be downright misleading to non-biologists. Circle diagrams, spiral diagrams, and bush diagrams, on the other hand, may have the necessary affordances to block the misconceptions reified by traditional representations of phylogenetic information.

Acknowledgment

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Chapter 10

Representations of the Origin of Species in Secular (France) and Religious (Morocco) Contexts

Dominique Guillo

Abstract

Many studies in the social sciences regard the rejection of evolution, creationism, and religious faith as closely related attitudes. The purpose of this chapter is to show that this explanatory schema is wrong and that representations of living species do not necessarily obey a binary logic based on the opposition between faith and reason, or religion and science. This chapter looks at and compares attitudes to evolution in two different countries, France, which is a laic country, and Morocco, where Islam is a state religion. In France, people claim to strongly adhere to "evolution" and reject "creationism." However, the representations of nature they associate with the word "evolution" come actually very close to that of Intelligent Design, the belief that the natural world displays clear signs of intelligent interventions. In Morocco, adherence to creationism seems motivated largely by rational as well as religious arguments. Most importantly, however, this inquiry underlines a major feature of these beliefs: they are often inherently blurred, because many individuals feel indifferent vis-à-vis the topic—the origin of species. Therefore, representations of living species are not universally and necessarily considered to be sacred, even though in many circumstances this is undoubtedly the case.

The reception of Darwinism is commonly analyzed within a framework that uses—or is similar to—the Weberian thesis of secularization through the advancement of science. According to this thesis, Darwinism has contributed to the "disenchantment of the world" by extending modern rationalism to the biological field. In doing so, the theory met with resistance from various religious movements. In the same breath it spread to nonbelievers—or less fervent believers—a conception of nature that was rid of creationist elements (I use the term "Darwinism" to designate all the propositions that are widely accepted in evolutionary biology; see Mayr).

The secularization thesis underlies much of current research on this topic in philosophy, cognitive sciences, and social sciences. These studies often rely on or develop the hypothesis that creationist representations of the origin of species are based on fallacious reasoning inspired by cognitive schemata that are deemed to be typical of faith (see, e.g., Dennett; Dawkins, *The God*; Coyne; Coleman). Conversely, adherence to a Darwinian representation of living species is considered to be the result of logically correct reasoning, supported with facts and free of references to occult entities, divine or metaphysical.

This general thesis predicts that the more religious people are, the more likely they will hold creationist views regarding the origin of species, oppose science and evolution, and, finally, reject the genealogical link between human and ape. Conversely, the less religious people are, the more likely they will develop scientifically sound, evolutionary representations of living species, will rely upon facts, science, and reason to support their beliefs about the origin of species, and reject creationism.

However, researchers who draw such a conclusion focus more often on actors actively involved in public debates concerning creationism: religious leaders, scientists, teachers, or biology students. The objective of this article is to show that a very different picture emerges when one studies the beliefs of ordinary actors less directly involved in these debates. I chose to compare two very different countries: France, a secular country in which creationism is almost totally absent from the public sphere; and Morocco, a country where religion plays a central role—Islam is the state religion.

I aim to demonstrate the following points. First, in order to understand the basis of creationism, it is imperative to distinguish between the content of the representation of the origin of species that individuals have, on the one hand, and their attitudes towards evolution, on the other. In my field studies, I observed that individuals who claim to accept evolution hold representations of the origin of species that, unknowingly, are not scientifically accurate, but that are, in fact, quite similar to creationist beliefs. Second, in Morocco, the majority of the participants did not straightforwardly reject evolution. Moreover, the arguments that people invoked against evolution were both rational—or, at least, perceived by the participants as such—and religious. Third, many individuals show a lack of interest in the issue of the origin of species, exhibiting a form of indifference that results in intrinsically blurred or vague beliefs. Finally, people do not always consider the origin of humans to be deeply sacred. For these reasons, beliefs about origins of species do not follow a simple and binary logic based on the opposition between faith and reason or religion and science, as the secularization thesis implies. In sum, the aim of this research is to bring about new insights concerning the actual cognitive basis of creationism, complementary to some avenues explored in this area of research (for example, in discussions about "cognition in context" proposed in Evans, "Cognitive," and her chapter in this volume; in Geraedts, "Reinventing"; and more broadly in Rosengren et al., *Evolution*).

France: A Non-Darwinian "Evolutionism"

In order to shed light on this logic, I first investigated people's attitudes towards, and understanding of, evolution in France (Guillo, *Darwin*). Here, I present one of the surveys on which I based my comparison with Morocco. I used a questionnaire on genealogical relationships between living species. On the first page of the questionnaire, I arranged six images in random order. These images represent "a chimpanzee," "a human," "an amoeba," "an oak," "a lizard," and "a whale." I wrote the name of each species in a caption under each photo. On the second page, I posed the following question: "Trace the genealogical tree that in your opinion connects these individuals to each other" (on how people interpret biological genealogical trees, see also the remarks and observations made by Shtulman, this volume; and more broadly on the effects of the use of such pedagogic tools, see also Blancke, Tanghe, and Braeckman, this volume).

With the experiment I investigated popular conceptions of the origin of species and measured to which degree these conceptions align with the scientific concepts in modern evolutionary biology. More specifically, I investigated whether or not the diagrams drawn by the students showed signs of the five schemata that characterize creationist beliefs about the origin of species (Mayr):

1. fixism, that is, the absence of genealogical connections between individuals of different species;
2. the Great Chain of Being, or Ladder of Nature, crowned by humans, that is, a linear and anthropocentric representation of the connections between species;

3. no role for chance;
4. an essentialist conception of species;
5. teleological thinking, a necessary consequence of each of the four previous schemata.

These five patterns lead to beliefs in extraworldly or supernatural entities—whether in the form of a personified god, metaphysical entities, or an abstract underlying order—that intervene in the formation of species. The 120 third-year students of a French scientific high school who participated in the study had been taught evolutionary theory in biology class, with an emphasis on how the theory breaks away from the five creationist schemata. This material was rehearsed two months before the experiment, in an Introduction to Social Sciences course. As we will see, in this sample, the results were highly convergent.

A Transformism Marked by the Anthropocentric Great Chain of Being

The first important result was that no student proposed a fixist representation of living species, not even partly: no species had been left unconnected to the others (table 10.1). The representation of the connection between species that emerges from these diagrams is unanimously transformist. But does the complete absence of the fixist schema in a sample of students from a country where secularism plays a central role validate the secularization thesis? Fixism, however, is only one of the possible components of creationist representations of living beings. In fact, all other creationist schemata are present in these diagrams.

First, there is the anthropocentric Great Chain of Being. Its most visible manifestations are, on the one hand, the linearization of diagrams—beings are connected in pairs by direct lines rather than branches or chevrons (or, in other words, a "V") representing a "common ancestor"—and, on the other hand, the crowning of these diagrams by humans (figure 10.1).

Table 10.1 Student responses regarding fixism and transformism.

	Nonresponse	"I don't know"	Fixist diagrams	Transformist diagrams	Total
Raw data	15	1	0	104	120
%	12.5	0.8	0	86.7	100

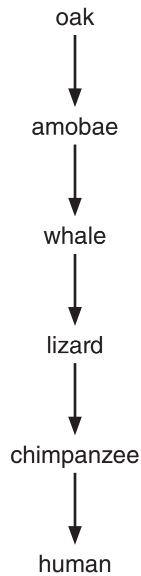

Figure 10.1 A Great Chain of Being crowned by humans.

These schemata are also present, despite appearances, in nonlinear, arborescent diagrams, similar to those in figure 10.2. Strictly speaking, the diagram in figure 10.2 is not inconsistent with a Darwinian interpretation. It draws a tree with branches that represent "common ancestors." Yet the Great Chain of Being profoundly regulates this diagram. Species' names are arranged along a line that clearly reproduces a scale following an anthropocentric and hierarchic criterion, which refers to their propinquity to the human being: at one end, oak and amoeba; at the other, human being, and just before her or him, chimpanzee. Note that it is quite possible to draw a tree without the human or the amoeba at one end, as is the case in the diagram (figure 10.3) proposed by another student.

Therefore, in diagrams such as figure 10.2, the reference to a common ancestor is interpreted from a scalar and anthropocentric perspective on living beings: the tree hides a ladder. Only in four diagrams does the schema of an anthropocentric Great Chain of Being play no organizing role (table 10.2). In sum, the overwhelming majority of participants' diagrams are organized according both a transformist and an anthropocentric schema (table 10.2). The conception of the transformation of species—of evolution—that emerges here is thus built from the idea of a linear temporal progression necessarily oriented toward the appearance of humans. A form of teleology, or progress, is clearly readable in this conception of life. It therefore leaves no room for chance.

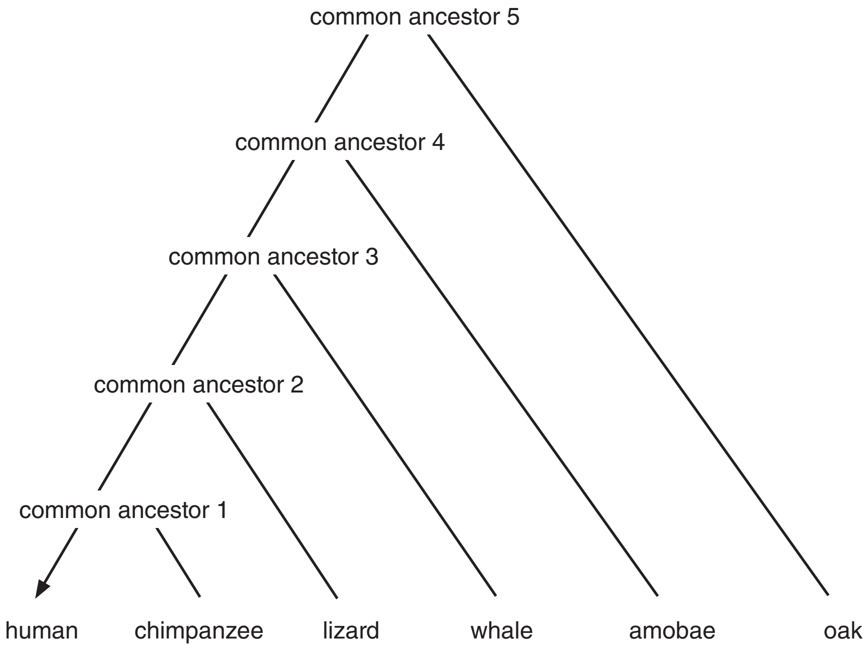

Figure 10.2 A less visible anthropocentric Great Chain of Being.

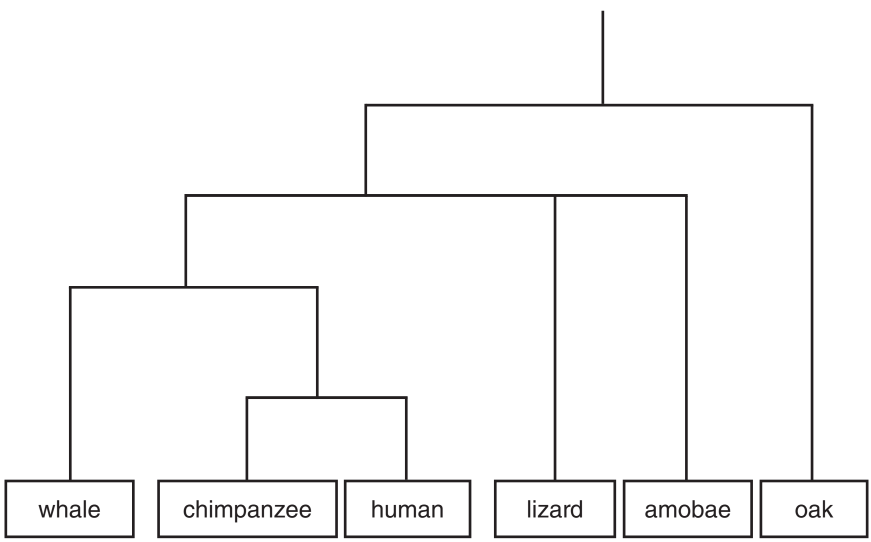

Figure 10.3 A tree without anthropocentric Great Chain of Being.

Table 10.2 Presence of the anthropocentric Great Chain of Being (GCB) (%).

Diagrams with GCB			Diagrams without GCB	Total
By direct linearization	Hidden ladder into the tree	Other		
72	20	4		
	96		4	100

Such representations of evolution are widespread in the French public sphere—in newspapers, popular scientific journals, educational textbooks, or documentary films (Guillo, *Darwin*). There are almost no public expressions of creationism. "Evolution" is frequently presented as a linear and ascending process of gradual complexification of species, which begins in the ocean depths with simple and crudely organized beings, evolving slowly through the ages to finally become human—the species with the most sophisticated mental faculties. This representation is perfectly summarized by the widespread formula: "man descended from apes."

In other words, the students I interviewed generally claimed to adhere to what science says and to "the idea of evolution." However, their adherence conceals a misunderstanding. Certainly, the representation they associate with the word "evolution" is transformist. As such, it breaks with the fixist beliefs typical of creationism. Nonetheless, their understanding of evolution remains strongly marked by teleology, anthropocentrism, essentialism (see Guillo, *Darwin*), and hostility to chance. This is definitely not a Darwinian representation of evolution (see Mayr, *What Evolution*; Dawkins, *The Ancestor's*).

An Evolutionism That Resembles Some Forms of Creationism

These results lead to two remarks. First, the strong teleological, essentialist, and anthropocentric undertones of students' representations of evolution explain why people can accept evolution and, at the same time, adhere to religion. We observed this close association between evolution and religion in a survey on readers' letters about evolution sent to a French popular science magazine—*Sciences & vie* (Sciences and Life) (Guillo, *Darwin*). In the eyes of many of the readers, evolution, as they understand it, requires a form of religious explanation, at least a reference to metaphysical entities or extraworldly forces. Within a teleological, essentialist, and anthropocentric framework, it is necessary to explain the direction evolution seems to take and the orderly progression it displays. Such statements demonstrate that, psychologically, there is no necessary link between adherence to religion, on the one hand, and rejection of the idea of evolution, rejection of science, or an explicit endorsement of creationism, on the other.

Second, students' representations of evolution are not in line with modern evolutionary biology, although students themselves think they are. In fact, in many ways, their ideas about evolution come very close to explicitly creationist representations, in particular to intelligent design, which accepts the transformist schema. The students claim to accept evolutionary theory, state they are "anticreationists" and consider their beliefs to be far more scientific than "creationists." However, within the fierce debates surrounding evolution, people who perceive each other as opponents often have very similar representations of living beings.

Of course, there is a very important difference between these two groups of people: the participants in this survey refer to evolutionary biology and, more broadly, to the scientific method. They tend to claim that the facts must decide on matters of natural phenomena. Conversely, militant creationists believe that religion and the authorities that represent it should have the last word. These are two radically different positions on truth, the type of arguments that establish it, and the authority of science in society. In other words, the real difference between the pro-evolutionary students and creationists lies much more in an ontological and epistemological register—how to establish the truth–and a social register—the status of scientific institutions in society—rather than in their representations of living beings, that is to say, in a cognitive or positive register. Therefore, on this point, these data lead to conclusions similar to those drawn in research showing that believers and nonbelievers very often mobilize the same fundamental "automatic intuitions" about the origin of species (see, in particular, Järnefelt in this volume, who shows that one can find even among nonreligious individuals an understanding of the origin of nature "as purposefully created by some being"). For this reason, creationism, the reception of evolution, and the creation-evolution debates cannot be solely explained by the opposition between two representations of living beings, one built on faith and religion, the other on reason and science. At least in this case, the secularization thesis is inadequate.

Blurred Representations and Lack of Interest in Matters of Evolution

After the questionnaire was completed I interviewed some of the students. It appeared that they do not have an extremely precise and definite opinion about the origin of species. It simply does not seem to be a matter of great interest to them (Guillo, *Darwin*). This applies to nonbiologists in general. I asked school teachers a question similar to the ones commonly used in surveys on the reception and the misunderstanding of evolutionary theory. In these studies, the researcher rearranges the answers of the participants in a particular order so that they are supposed to reflect his or her beliefs about evolution (see, for example, Bishop and Anderson, "Student"). In the experiment I conducted, I recorded the dialogues between the experimenter and the interviewee, to capture the modalities of expression, the properties, and the strength of the participants' conviction. The problem I posed was about the evolution of the giraffe's neck. E designates the experimenter and JD are fictitious initials for the interviewee (the dialogue is here translated from French: for a detailed presentation of this experiment, see Guillo, *Darwin*).

E: How would you explain to a child the steps of the evolution that led to the formation of the current giraffe's long neck, knowing that their ancestors had short necks?

JD: I write that?

E: No, no, you just explain.

JD: I just speak . . .

E: Yes, yes, you speak.

JD: So they had short necks . . .

E: The ancestor of the giraffe, it has a very short neck, so how did the first giraffe with a long neck appear?

JD: Well it's in relation to food, because they had to . . . [*silence*].

E: Yes. [*laughing*]. I do not know, me, don't look at me this way, I don't have the slightest idea . . .

JD: I've gotta talk to someone.

E: Yes, yes, go on.

JD: And why did they have to . . . It means that there was nothing left to eat on the ground or um . . .

E: Yeah.

JD: Why was there nothing left to eat on the ground? Well there's been climate changes that made it impossible to find something to eat on the ground . . . but at the same time it means that there was a drought, so normally there should be no more trees . . . So why . . . To have access to food that was not eaten by other animals? I do not know, I don't have the answer.

E: Okay. Then a change in environment, well, in vegetation . . .

JD: Adaptation to the fact that . . . Thanks to their long neck they have access to branches to which other animals that use to eat plants do not necessarily have access.

E: Okay, and how did that happen? How there were the first long-necked giraffes among short-necked giraffes? How did that happen?

JD: Well it is an evolution . . . you know . . . genetic, you know, progressive.

E: Okay.

JD: Natural, which involves an adaptation, you know. They had no choice, in fact, either . . . Well there was a time . . . To thrive and survive, this species has had to adapt, and it succeeded in adapting, you know.

E: Okay.

JD: So with a long neck, well, that was doing better for feeding you know.

E: OK. All right?

JD: Yes.

It might be tempting to consider that JD entertains in his or her answers a teleological—here a "lamarckian"—schema: "well that was doing better for feeding." These are the conclusions drawn by a lot of research on this issue (see for example Bishop and Anderson, "Student"). However, such an interpretation of the data underestimates the long distance between, on the one hand, words or sentences with finalist accents—such as those pronounced by JD—and, on the other hand, finalist beliefs about living beings in the strong sense, that is to say some kind of theory—here teleological or Lamarckian (on this point, see insightful observations and remarks in Geraedts and Boersma, "Reinventing"). Indeed, if one focuses on the elements of the dialogue that reflect the individual's relation to the belief attributed to him or her, it appears that the few words he or she utters—"it's an evolution," "which involves an adaptation"—seem to the interviewee very quickly a sufficient explanation, that answers the question with a satisfactory degree of precision. These concepts, however, have only a vague meaning in the mind of the interviewee. They do not seem to refer to a range of questions that she or he uses to explore in depth, about which he or she uses to have an opinion or specific beliefs. Certainly, cognitive content outcrops here. Nevertheless, it would be a long stretch to translate these vague expressions into logically ordered propositions with a specific and precise content, that is to say, into a theoretical discursive system. More broadly, in many interviews I conducted, people often displayed feelings, postures, and attitudes such as discomfort, laughs, and confessions of ignorance—"I don't know"—or referred to scientific authorities for an answer. These words and postures express a low intensity commitment and a form of distance and indifference towards the origin of species.

It should be emphasized that these words and postures need to be taken into account in the description that the researcher gives of such beliefs. They should lead her or him to characterize these beliefs as intrinsically blurred in part. This property—or variable—is rarely mentioned. In particular, in cognitive research on representations about the origin of species, the responses of the individuals interviewed are very often transcribed into propositions considered as having a precise semantic content. This semantic content is generally described as different from the one that the same proposition has in biology (for example, the proposition "living beings are genealogically interconnected"). It is also generally considered to be false or to lead to false conclusions (for example, the proposition: "the natural phenomena have been all 'purposefully created by some being'" [Järnefelt, this volume]). Nevertheless, in these studies, the propositions are very often treated as semantically precise. If they are not, they cannot be regarded as strongly jump-starting participants' biological reasoning. However, the interviews I conducted show that this hypothesis needs to be nuanced: clearly, in the minds of some people, the semantic content of the cognitive elements that form the "intuitions" about the origins of species is inherently vague and the public expression of these "intuitions," as their ontogeny, are context-dependent in large part. Certainly, they are not entirely context dependent: but, for a lot of people, these intuitions are partly fuzzy. This fuzziness plays a key role in the relationship between scientific discourse, religious faith, and ordinary representations of natural beings, as I try to show in the third part.

Morocco: What Kind of Creationism?

I followed up on these investigations in France with a study in Morocco. The goal was to make a comparison between two very different contexts. Indeed, religion plays a central role in Morocco: Islam is the state religion. The Koran contains passages that explicitly mention the divine creation of humans. Therefore, this context is very relevant and promising for testing the impact of a strong public presence of religion on common representations of the origin of species.

To compare with the French case, I posed the question about the genealogy of living beings to 97 first- and second-year political science students at a Moroccan University. I chose political science students, not science students, as I did for the French case. My hypothesis was that people's representations on this subject are not exactly those that could be expected given the respective traits of the public sphere in these countries—secular, in France, religious, in Morocco. Therefore, it seemed to me that my demonstration would have more force if I succeeded in showing, on the one hand, in France, that even among students who have received a solid scientific background, the representations are quite far from what science actually says, and that, on the other hand, in Morocco, even among students who have not studied science, the representations are both less hostile to evolution and less directly determined by faith that we might think.

The students mostly belonged to higher social classes. The vast majority of them had not studied the question of the origin of species during their schooling. Most of those who had studied in French schools located in Morocco—a minority in my sample—were in literary studies. The others—a large majority—had studied in Moroccan education system schools. The Moroccan school programs do not cover the question of the origin of species, even in scientific curricula, which are yet very rich and varied on other subjects such as genetics. In fact, biology textbooks mention neither evolutionary theory nor creationism. At the same time, religious authorities actively promote creationism in the public sphere.

Changes to the Experimental Protocol in This Context

I adapted the questionnaire to the specificities of the Moroccan context. First, I had it translated into Moroccan Arabic. Second, as I assumed that there would be many more creationist representations than in France, I chose to offer three possible answers, in order to better analyze the content of students' beliefs. These three answers were:

1. "there is no genealogical link between these beings"
2. "there are genealogical links between some of these beings"
3. "there are genealogical links between all these beings"

For responses 2 and 3, I asked students to draw a genealogical tree. The aim of the distinction between responses 2 and 3 was to enable individuals to establish some connections and to exclude some others. With this distinction, I wanted to find out whether the reluctance vis-à-vis the idea of evolution is rooted in the sacred status given by religion to humans, as the secularization thesis predicts. If this hypothesis was correct, we should observe that people are more reluctant to establish a link between the human and the ape than any other link. Moreover, we should observe that the closer living beings are to humans, the more reluctant people are to establish genealogical links between them.

As in France, the questionnaire was anonymous. It was distributed to students after an examination. This way I avoided face-to-face interviews—a situation that tends to cause considerable bias when discussing the origin of species in religious contexts. It also prevented students from communicating with one another before, after, or while they responded to the questionnaire.

The results are different from those that I collected from the French students. However, they have something very important in common. Again, they show how simplistic and dubious the secularization thesis is, by attesting that the rejection of evolution is not simply the product of cognitive biases in reasoning caused by a blind faith in religion.

Integral Fixism Is a Minority Position

The first important result is that integral fixism—that is to say, the hypothesis of a total absence of genealogical links between living beings (response 1)—is not a majority viewpoint. It is chosen by 36.1% of students surveyed, against 29.9% for partial transformism—response 2—and 18.6% for integral transformism—response 3—giving a total of 48.5% for the two variants of transformism. In sum, fixist creationism is present in this population of students from higher social classes, but it is far from unanimous (table 10.3). Note also that the vast majority of students who refused to establish any genealogical connection—response 1—did not make any explicit remark concerning her or his commitment to faith, although I had provided some space on the answer sheet for any comment they wanted to make. Only three students mentioned God or religion.

A Transformism That Resembles That of French Students

Detailed analysis of the diagrams proposed by students who chose a transformist response—partial (response 2) or integral (response 3)—provides additional information and teaches us valuable lessons. First, many diagrams leave out some living beings—response 2—without links, sometimes even without mentioning them, like the following (figure 10.4). More generally, none of these diagrams can be regarded as strictly compatible with the theory of evolution (such diagrams, however, were also very rare among French students). Certainly, some diagrams have a tree structure and one of them even refers to "common ancestors"

Table 10.3 Moroccan student responses regarding fixism or transformism.

	Response 1: Total absence of links	Response 2: Links between some species	Response 3: Links between all species	Non-response	Total
Raw data	35	29	18	15	97
%	36.1	29.9	18.6	15.4	100

(figure 10.5). However, most of the collected diagrams are composed of lines connecting directly beings in pairs, and more rarely by branches that may represent a common ancestor. The human species is located each time at a particular place, obviously eminent, either at one end of the diagram or apart.

In total, these diagrams (figures 10.4 and 10.5) are obviously underpinned by the same schemata as in the "evolutionary" representation of nature observed in France: a transformism based on the anthropocentric ladder of nature, which implies a form of teleology and a denial of the role of random chance.

The Major Role of a Positive or Rational Criterion: Differences in Appearance between Living Beings

A probably even more important fact emerges from the transformist diagrams. This is related to the hypothesis I wanted to test by distinguishing responses 2 and 3. These diagrams suggest that the reluctance to establish a genealogical link between living beings is not always—or not only—rooted in the demands of faith, in opposition to reason. As noted above, if faith was the only principle guiding the choice whether or not to connect each being to another, the link between human and ape should be the least represented in the diagrams collected, being the most potentially sacrilegious. However, we observed precisely the opposite. The human/ape link is by far the one that was preferred by students who traced genealogical diagrams: 68.1% of these students—33% of all students surveyed—established a link between these two living beings. Far behind come human/bacterium and oak/bacterium links, established by 51.1% of these students—24.7% of the total (table 10.4).

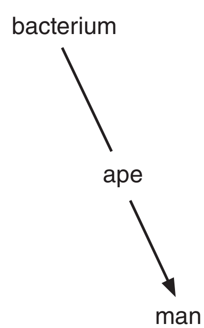

Figure 10.4 A diagram linking only three beings. Written in Moroccan Arabic.

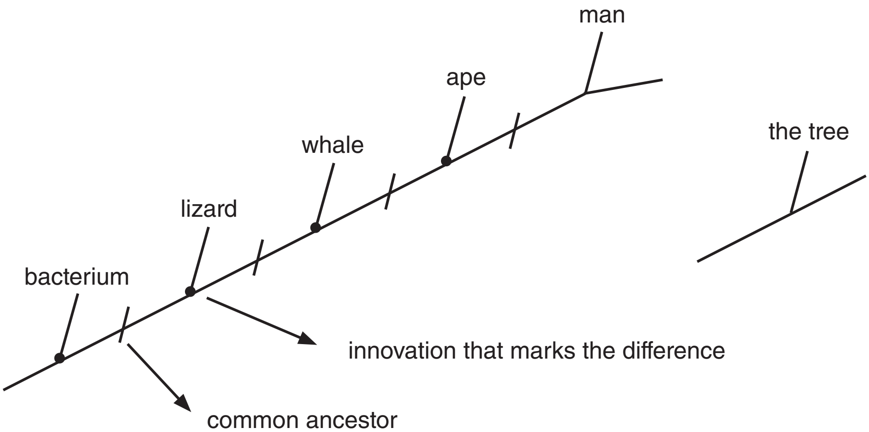

Figure 10.5 A diagram referring to common ancestors. Written in French.

Moreover, the living being that participants connected most to another species—whatever the latter—is the human being. It is associated with another species in 89.4% of diagrams, that is to say, 43.3% of total responses. Then comes the ape—80.9% of diagrams (39.2% of total)—and then the bacterium—78.8% (38.2%). The most neglected being was the oak: 46.9% (22.7%) (table 10.5). These data show that students who do not subscribe to an integral fixism preferentially establish a link with the human species. Even more significantly, the students seem much less reluctant to draw a genealogical connection between a human and an ape than any other conceivable link (table 10.4)—fifteen links between two beings are possible here. Therefore, their position on transformism and fixism does not seem to be motivated only by faith, because if that were the case, we should see the strongest reluctance to establish genealogical connections when humans are involved.

Such data invite us to make a different assumption. They suggest that some kind of positive, or rational, at large (Boudon, *The Art*), criterion or argument, and not only emotional—sustained by faith—plays a key role in the formation of beliefs about transformism and fixism. This criterion is the perceived degree of similarity between living beings, except in the bacterium case, however, a very special one (on this case, see Guillo, "Le Créationnisme"). Hence, it seems that people refuse to admit the existence of genealogical connections, that is to say, refuse transformism, because, as they understand it, it forces them to endorse assumptions that they think are empirically very doubtful—for example, that

Table 10.4 Number of direct links between two species.

	Raw data	% of responses 2 + 3	% of the total of responses
Human/Ape	32	68.1	33
Human/Bacterium	24	51.1	24.7
Oak/Bacterium	24	51.1	24.7
Lizard/Bacterium	23	48.9	22.7
Whale/Bacterium	22	46.8	21.7
Ape/Bacterium	21	44.7	14.4
Whale/Lizard	14	29.8	11.3
Ape/Oak	11	23.4	10.3
Lizard/Oak	10	21.3	9.3
Ape/Whale	9	19.1	8.2
Human/Oak	8	17	6.2
Human/Lizard	6	12.8	6.2
Ape/Lizard	6	12.8	6.2
Whale/Oak	6	12.8	6.2
Human/Whale	4	8.6	4.1

Table 10.5 Number of links established for each species with other species.

	Raw data	% of responses 2 + 3	% of the total of responses
Human	42	89.4	43.3
Ape	38	80.9	39.2
Bacterium	37	78.8	38.2
Lizard	29	61.8	29.9
Whale	27	57.5	27.9
Oak	22	46.9	22.7

a tree, or a lizard, could have given birth through its successive descendants to completely different beings such as a whale or a human.

This hypothesis could explain why a majority draws a connection between humans and apes: the two individuals that were in the photos I used looked the most similar. It also accounts for the setting aside of the tree, insofar as the tree looks very different, apparently, from all other living beings proposed in the questionnaire. Symptomatically, one of the students wrote (in French): "there is no connection or similarity between these living beings."

In general, it is possible that the transformist thesis, as these students understand it, namely, that "this living being A descended in direct line from this living being B," offends their reason as well as—and perhaps, for some students, more than—their religious faith. In the minds of the students, there does not seem to be a tension between religion, on one side, and what the facts and common sense suggest, on the other. In sum, the secularization thesis needs to be seriously nuanced again (for nuanced conclusions about the reception of evolution in Muslim contexts, see also Koning, "Anti-Evolutionism").

A Hypothesis Confirmed by Interviews Concerning the Questionnaire

To strengthen these assumptions, I conducted interviews about the questionnaire with some of the students, but also with people from very different social classes (this survey is currently being pursued systematically and on a larger scale). More widely, the goal was to identify more precisely how the question was interpreted by interviewees and so to better grasp the meaning of their answers. Three key lessons emerge from these interview series. They confirm the assumptions made above.

First, for most of the interviewees, differences in appearance between living beings are key in doubting the existence of genealogical links between them. This remains true even when the interviewer suggests that one must imagine a very long time and a huge number of generations between living creatures.

Second, people in Morocco do not always understand the question in exactly the same way as in France. The different words that could be used to suggest to the interviewee that the question was about the family tree drawn by biological kinship, and only that, were spontaneously invested with meanings that were somewhat floating and different. These meanings very often included implicitly, and sometimes quite explicitly, nonbiological ties, like filiation between adoptive parents and adopted children, for example. Of course—and this point needs to be strongly emphasized—people understand the idea of a purely biological conception of genealogy, including the groups it builds and the nature of the relationships it draws between individuals. However, unlike a biologist, they do not use this definition or categorization of kinship very often in their daily life. Therefore, one should be extremely careful about the conclusions that can be drawn from such questionnaires when they are not accompanied with in-depth interviews or ethnographies. Indeed, the meaning given to the question by individuals—and therefore the meaning of the answer they give—may both differ from the one that the researcher had in mind when she developed her experiment. In such a case, the answers may differ from one another—and even be literally conflicting—not because individuals have contradictory beliefs, but simply because they do not answer exactly the same question. Therefore, one must avoid drawing hasty conclusions from such answers, as some surveys do, using directly those data to decide whether people in a cultural area or a social group "believe in evolution" or "are creationist" (see for example Gallup polls, as in Newport, "In U.S.")

Third, in my sample of students in Morocco, the rejection of evolution does not seem to be part of a rejection of science in general. Religion and science are rarely presented as institutions or beliefs in tension, unlike what can be observed, for example, in the discourses of some neo-evangelical activists in the US. Conversely, people very often reject evolution in the name of science—as they perceive it—as well as religion.

Finally and more importantly, as in France, the question of the origin of species does not always seem to have a strong sacred dimension. Furthermore, evolution does not always seem to be very strongly sacrilegious (at least so far, because the situation can change). This is what we observe in the interviews with the students discussed above as well as in the ones I am currently conducting with people from other social classes in Morocco. In these interviews, many people speak about God's creation of living beings. They also mention that they know that Westerners think that "man descended from apes." Interviewing them about evolution sometimes generates some emotional reaction, a will to express a conviction. But these reactions are, so far, often very slight, compared to the ones generated by issues directly related to morals or religious matters. Above all, frequently, interviewees do not show a keen interest in these issues, which are devoid of direct practical moral implications. It is not uncommon for individuals to show a low level of commitment, except when they express an intense and militant faith, combined with a discourse against the West. Therefore, here again, the secularization thesis seems to be fragile. The same applies to a famous hypothesis by Sigmund Freud: here, evolution does not always seem to inflict a great "narcissistic wound" on believers.

Cognitive Indifference and Blurred Representations of Living Beings

The indifference that people sometimes display concerning the object and the accuracy of their own beliefs is often overlooked by social and cognitive scientists in their investigations on the relationship between ordinary knowledge, science, and religion. However, this fact is extremely important in understanding the logic behind these beliefs. What really distinguishes between the representation of the origin of species of an evolutionary biologist, on the one hand, and that of a nonexpert in biology, believer, or nonbeliever—at least when she or he is not a creationist activist or an amateur, passionate about science—on the other hand, is actually not their respective contents. It is first and foremost their degree of detail, their degree of accuracy, and the strength of the commitment that accompanies them. The representations of the biologist are very precise and detailed, the other two—those of the believer and the nonbeliever—often much more blurred.

This is the reason why in many cases there can be no real contradiction between the beliefs of scientists and lay people—even in cases where people perceive their respective beliefs as mutually contradictory. Scientists' beliefs, on the one hand, and laymen's beliefs, on the other, cannot really be considered as contradictory, not because their contents would be incommensurable, but simply because they differ too much in degree of precision to allow for a comparison; scientific beliefs are usually developed with care and with a strong commitment by a specialist who devotes all her or his time studying living beings. In contrast, laymen's beliefs are often marked by a form of partial indifference, by which the justification is delegated to authorities regarded as competent. As a result, these beliefs are left epistemologically fallow. To put it in another way, a fuzzy representation does not oppose a precise representation, whatever their respective contents. For the same reason, in many cases, there can be no real match between the scientific discourse on evolution, on the one hand, and representations shared by nonspecialists who adhere to evolution and the science, on the other.

Both social sciences and cognitive sciences should take this fact very seriously. In research on representations, beliefs, or knowledge, hesitation, the discomfort or indifference expressed by interviewees is almost always considered a methodological obstacle to be overcome in order to reach the content of individuals' real "belief" or "representation." The task of the researcher then becomes to track down some latent knowledge, representation, schema, cognitive biases, automatic intuitions, folk biology, or underlying modules specialized in the treatment of a type of information—in this case, information about the classification and origin of species (Medin and Atran, *Folkbiology*). One might wonder what the researcher is doing by following too far this approach. How far should he or she go? Is there not a risk to collect partly an artifact, in ordering too strongly interviewees to provide justifications and explanations about questions that they may never have asked? Finally, should we not see these hesitations, signs of discomfort, and disinterest as cognitive and anthropological data first, rather than methodological obstacles?

The fuzziness of people's beliefs could be more deeply taken into account in the social and cognitive studies that look into laypeople's representations of and attitudes towards scientific concepts and theories. Certainly, some studies acknowledge it by using the term "intuition" rather than "theory" to qualify these representations or by emphasizing the context-dependent aspects of their public expression. However, its importance is still often underestimated, which has consequences. It leads to partly overestimate the weight of independent cognitive factors—as "biases" or "automatic intuitions"—that impede people's understanding of evolutionary theory. Actually, some people have in mind less precise private mental representations than the experimenter suggests they have, when the latter treats the sentences they utter in experimental situations as propositions with precise content. In sum, on these issues, rather than having erroneous theories—or even sometimes "intuitions"—some people do not have well-articulated beliefs. Of course, this is not true for most activist believers, starting with those who have targeted evolution among Christian and Muslim movements (see, for example, Yahya, *Atlas*). Here the opposition is frontal, lively, more based on arguments—even though, of course, these arguments are false and based on mistakes and fallacies. Such individuals show a strong commitment. Such activism has, undoubtedly, a political and media impact, especially on beliefs of nonspecialists in biology. However, I would like to emphasize that one should not conclude from the existence of such movements that the theme of the origin species contains in substance a necessary matter of conflict, at least psychologically. This issue is not always conceived as highly sacred, including by believers—and even then, in some cases, only a little. Therefore, contrary to what a superficial interpretation of the often heated debates in the US suggest, evolution becomes controversial only in specific historical circumstances, in which religious groups are able to give the issue a highly sacred meaning, with major moral and political implications.

The reception of evolution obeys an infinitely more complex logic than assumed in the secularization thesis. There exists neither a necessary conflict nor an ineluctable convergence between ordinary believers and nonbelievers on the issue of the origin of humans and species. Instead, a complex interplay emerges between people's actual representations of living beings, the mutual perception and labeling of one another's representations, and the historical context in which beliefs unfold and spread. This interplay opens a space for beliefs and interactions that are marked by a large uncertainty. Considering all these factors together is crucial to ensure an effective dissemination of evolutionary theory, especially in education.

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Part 3

Epistemological Perspectives

Naturalized epistemology takes insights from the cognitive sciences to develop a broad understanding of how people generate and sustain scientific knowledge, which is a classical philosophical theme. The starting point is that humans are limited biological beings that rely on all sorts of help to arrive at a scientific understanding of the world. This help includes conceptual, observational, and reasoning tools, but also dependence upon other people's expertise and criticisms by peers. As such, science proceeds through the interaction of numerous human minds, with their specific abilities and limitations, with one another and their environment. An epidemiological approach provides us with the theoretical framework to identify and map the cognitive and environmental factors that affect the forms and distribution of scientific concepts, in science, science education, and the public understanding of science. Such an approach, which integrates historical, sociological, rhetorical, cognitive, and philosophical approaches to science, does not infringe upon but provides us with a rich naturalistic causal account of science's epistemic superiority.

Chapter 11

Updating Evolutionary Epistemology

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Abstract

This chapter critically analyzes evolutionary epistemology as a theoretical framework for the study of science as a historical and cultural phenomenon. As spelled out by Campbell in the 1970s, evolutionary epistemology has an ambitious goal: it aims at understanding the complex relations between biological evolution, especially the biological evolution of human cognition, and the cultural evolution of scientific knowledge. It eventually aims at forming an integrated causal theory of the evolution of science, starting with the evolution of human cognition. In this chapter, the author considers Campbell's project and specifies why it is still today a worthwhile project for explaining the evolution of science as a specific case of cultural evolution. But he also criticizes Campbell's evolutionary epistemology for assuming that blind variation and selective retention are the processes through which science evolves. This assumption, the author argues, is at odds with much of what we know about scientific cognition and the history of science. He advocates (1) dropping the methodological constraint of looking for processes of blind variation and selective retention at the expense of other constructive processes and mechanisms of knowledge production; but (2) retaining the integrative point of evolutionary epistemology, which implies taking seriously the results of evolutionary psychology; and (3) retaining the populational framework for explaining the history of science, which means questioning why some scientific beliefs and practices eventually spread and stabilize in a scientific

community. We end up with an updated research program for evolutionary epistemology, which faces new challenges.

Campbell on the Evolution of Scientific Knowledge

Campbell introduces evolutionary epistemology as a research program in descriptive epistemology "that would be at a minimum an epistemology taking cognizance of and compatible with man's status as a product of biological and social evolution" ("Evolutionary" 413). Evolutionary epistemology aims at providing a causal history of scientific knowledge that not only accounts for the human history of science making, but also includes accounts of the cognitive processes at the basis of this history, and of the evolutionary history of the cognitive abilities implementing these processes. Evolutionary epistemology is therefore an integrated research, which spans biology, evolutionary psychology, cognitive psychology, sociology, and history. For instance, Campbell, following Konrad Lorenz, advocates the understanding of Kant's categories of perception and thought as evolutionary products ("Evolutionary"). Thus, Campbell applies evolutionary biology to human cognition, elaborating thoughts much akin to contemporary evolutionary psychology.

Another point that Campbell makes, which was developed by David Hull and which I criticize in this chapter, is that science evolves by means of blind variation and selective retention. According to Campbell, blind variation and selective retention together make the single principle at work at the levels of natural history, thought processes, and science history. It is the principle that is generalized from Darwin's theory of natural history and applied to science studies. It is meant to account for scientists' creative thinking and the cultural evolution of science. Concerning the history of science, Campbell fully takes on Popper's account of the "logic of scientific discovery" and its principle of "conjecture and refutation." Concerning creative thought, Campbell develops his own argument, which puts at the center stage of creative thought the "eureka" phenomenon ("Blind Variation"). For Campbell, blind selection and selective retention are necessary processes of evolution: evolution implies the generation of genuinely new items, which means that the generative process cannot be biased by the value of the items (in terms of fitness); the generative process does not embed knowledge of the value of the new items. As analytical truths about evolution, or as abstract principles that can always describe, at some level, the processes of evolution, there is nothing to say against blind variation and selective retention. Yet, I argue that when one attempts to explain the detailed causal processes through which cultural evolution takes place, then, blind variation and selective retention are insufficient analytical tools.

Thus, one can distinguish several projects under the label of evolutionary epistemology. The most radical project is the application of the Darwinian selectionist model in order to account for the evolution of knowledge. I argue that this project, although inspiring, can unduly limit research about the processes—cognitive and social—at work in the production of scientific beliefs and practices. But a more modest understanding of evolutionary epistemology would advocate the two following more fundamental projects:

1. The naturalization of epistemology as passing through population thinking: population thinking for the history of science consists in analyzing scientific theories and practices as populations of thoughts and ideas that are realized in mental states of actual scientists, of behaviors that are repeated (think of, say, running a specific statistical test), of scientific tools that make the environment of scientists. Populations are sets of actual items that grow, shrink, or are maintained in time. Populations of mental states, behavior, and artifacts are the actual realization of macro-social phenomena. For instance, the success of a scientific theory is the fact that the population of mental states and behaviors associated with the theory is not shrinking with time. The naturalism involved here is concerned with ontology: one must attempt to explain what macro-social entities refer to in terms of natural, or material, entities only. Population thinking requires specifying which natural entities constitute cultural phenomena, and the processes through which these entities are distributed in human communities and their habitat.
2. The naturalization of epistemology as a theory of knowledge production that is, as Campbell puts it, "taking cognizance of and compatible with man's status as a product of biological and social evolution." In effect, this means that evolutionary epistemology is an interdisciplinary project that studies (1) biological evolution, as the cause of the existence and nature of the human cognitive apparatus; (2) cognitive psychology, as the description of the processes through which mental representations are constructed by the evolved human cognitive apparatus; and (3) history, as the description of the particular chains of social events that eventually constitute scientific evolution. This project is naturalistic because it aims at showing the connections between natural sciences, such as biology, and the social sciences, such as the history of science. There are layers of processes constructing

> elements for the next layer of processes: biological evolution constructs biological cognitive apparatuses that construct, when interacting with the environment, representations, which are elements out of which scientific knowledge is made.

While Campbell based his integrated model of scientific development on the single principle of blind variation and selective retention, which would account for natural history, the dynamic of thought, and the history of science, I argue that different processes are at work at each level and that Darwinian selectionist theory (i.e., evolution occurs via blind variation and selective retention) does not necessarily apply to scientific cognition and to the history of science. Integration does require showing how biological, cognitive, and historical explanations match and combine into a single more exhaustive account, but there is no need to assume that the explanatory principles that account, respectively, for natural history, cognition, and social history are the very same. More precisely, I point out that current theories in sociology and cognitive psychology describe mechanisms for the production of knowledge that differ from blind variation and selective retention. The conclusion is that the Darwinist selectionist model of evolution applies to the evolution of epistemic mechanisms (EEM) of the structure of the brain, but do not extend to an evolutionary epistemology of theory (EET) (typology introduced by Bradie ["Assessing"]). I argue that there are two problems with an EET that assumes blind variation and selective retention of scientific ideas and practices: the first is blind variation, and the second is selective retention.

Blind variation does not describe properly the generation of new scientific ideas and practices, because the processes of discovery might not differ so radically from the processes that enable the spread of the idea. In other words, discovering and learning a scientific concept, a theory, or a practice rely on partly identical cognitive mechanisms. This is in stark contrast with biological evolution, where genetic variation occurs at molecular levels following principles that have nothing to do with the principles of selection, which occur at the level of the reproductive success of the organisms having traits whose development was favored by the genetic variant. Rather than blind variation, the cognitive processes of discovering and learning are grounded in (a) the evolved cognitive abilities and principles that characterize the human mind, (b) previously acquired knowledge and skills, and (c) the constructed social environment.

Selective retention does not describe properly the spread of new scientific ideas and practices because these are constantly changing, being interpreted and reinterpreted by different scientists in different context. The question is therefore why, in spite of these changes, the ideas remain strikingly similar, at least for a given time and within a given community. There are diverse social and cognitive mechanisms that determine how types of representations stabilize in the scientific community. Expressing an idea, interpreting it, applying the idea to new contexts or problems, learning a practice, and so on: these are complex processes that are not processes of replication. First, it is rarely the intention of the scientists to faithfully replicate and, second, there are many cognitive mechanisms involved, whose function is not replication. These mechanisms inevitably induce variations that, sometimes, converge towards the same type.

In brief, the processes that lead to biological, cognitive, and cultural constructs are not necessarily of the same kind. Biological stages are indeed characterized by blind variation and selective retention, but cognitive stages are achieved through the functioning of evolved capacities of perception, understanding and learning. Finally, cultural stages involve, of course, social interactions allowing mental and public representations to stabilize within the population of scientists, through processes such as education, feedback loops, and so on. There is a wealth of social and cognitive processes out of which scientific knowledge is constructed and spread. In the spirit of evolutionary epistemology, one goal is to integrate the results from evolutionary psychology, the psychology of science (including psychology on creativity), and the sociology of science. But this integration cannot but be hindered by further attempts to impose the Darwinian selectionist model on all processes, at all levels, of knowledge making. In the next sections, I consider the limits of blind variation for explaining scientific creativity. I then specify some of the research questions and challenges that integrating evolutionary psychology to the study of scientific creativity raises. Second, I consider the limits of selective retention for explaining the spread and success of scientific ideas and practices. I then specify some of the challenges that evolutionary epistemology faces.

Blind Variation Does Not Accurately Describe the Processes of Scientific Creativity

Blind variation and selective retention require a decoupling of variation and selection. But are psychological processes of scientific belief formation based on blind hypothesis formation? An important motive for including blind variation in scientific cognition comes from Popper's arguments against inductivism: it is never sufficient to gather data for creating knowledge; scientists have to develop new hypotheses for accounting for the data. Induction does not solve the problem of scientific creativity, "trial and error" does.

Kronfeldner develops a careful analysis of how blind variation is understood when describing scientific hypothesis formation ("Darwinian"). It is not, she warns us, to be understood as completely random variation, since hypothesis formation is strongly constrained by human cognitive capacities, sociohistorical context, and the state of knowledge. It remains that creative hypothesis formation is blind, meaning that the occurrence of new ideas is not influenced by factors that determine the selection of these new ideas. More precisely, it is blind in the sense that generative processes are not attached to any justification of the hypothesis. The idea behind this "blind as unjustified" account of hypothesis generation is in line with Popper's criticism of induction. A scientific hypothesis is justified (corroborated would be a better term here) when it has passed many attempts to falsify it. The thesis thus specified says little, as Maria Kronfeldner remarks, of the cognitive processes of discovery and hypothesis formation. So we remain with blind variation being a random production of ideas, but within a subdomain of possibilities constrained by psychological and contextual facts. However, Campbell brings another interesting specification of cognitive processes: a satisfying halting procedure. As he himself notes, blind search implies an enormous number of possible thought trials to be searched before one can select a solution. The tremendous number of nonproductive thought trials that blind variation and selective retention necessarily produce make the cognitive system unfit for survival, where decisions need to be taken quickly (e.g., when facing a predator) and where energy resource is rare and scarcely allocated ("Blind Variation").

Campbell's solution to the above problem is to postulate the existence of a simple stopping rule for the search: being selected when answering some criteria. Campbell is aware of the problem of informational explosion that blind search can create (he refers to Newell et al.); he acknowledges the credibility of the heuristic approach. He consequently allows its system to incorporate "shortcuts" to full blind variation and selective retention processes, thus making a nested hierarchy of selective retention processes ("Evolutionary"). Domain-specific heuristics, innate knowledge, or Kantian categories are such shortcuts because they allow compiling the solution without blind search or through limiting the blind search to a restricted domain. It thus turns out that even if one follows Campbell's ideas on human cognition, explaining the generation of ideas still requires specifying human-specific cognition, while the explanatory role of blind variation is small. Campbell nonetheless quickly points out that (1) such human cognitive abilities are themselves produced through blind variation and selective retention; and (2) "such shortcut processes contain in their own operation a blind-variation-and-selective-retention process." Within the perspective of evolutionary psychology, the first point is granted, at least to the extent that the cognitive processes result from evolved cognitive abilities.

However, acquired skills and knowledge should also be taken into account for understanding generative processes. This might not be a minor point, since learning itself is probably not a blind variation and selective retention process. The second point, that the evolved cognitive mechanisms themselves implement blind variation and selective retention, is even more problematic: it is an empirical claim about human cognition that has received little support from contemporary cognitive psychology. The set of possible constraints that affect both creation and reception goes well beyond "pre-adaptations" or "developmental constraints," which Stein and Lipton show to bias both biological and scientific evolution ("Where Guesses").

The variations that make up new knowledge are guided by both ideas acquired from the cultural background and evolved mental mechanisms. This is granted by Campbell. What make these variations not blind is that these same processes are involved in modulating the success of these generated ideas. This is because the ideas that can be easily learned and that are built upon existing cognitive resources are more likely to be successful than ideas that have no such grounds. The reception of a new scientific idea depends on the understanding of the communicated idea. But this understanding is itself a creative process whose success is rendered possible because the audience has similar cognitive abilities and shares the same background knowledge as the one expressing new ideas. Finally, the background knowledge involved in the generation of ideas also contributes to their relevance to the community having the background knowledge. For instance, the relevance of calculus—and its cultural success—is increased by its applications to mechanics. But Newton invented calculus exactly for solving problems in mechanics. These aspect of science making constitute a strong connection between generations by individual scientists and selection by the scientific community. There is therefore a coupling between variation and success such that blind variation cannot be said to properly characterize scientific creativity and the success of scientific ideas and practices. At a minimum, the Darwinist framework seems, at this point, to hinder rather than foster research, as it unwarrantedly denies connections between creative processes and factors of reception.

Campbell is misled by the examples he takes as paradigmatic thought processes because he heavily relies on scientists' intellectual discoveries and their phenomenological accounts, such as the Eureka phenomenon and Poincare's essay on mathematical creativity. But according to Campbell's own emphasis on the cognitive apparatus as an evolved organ, scientific inventions can hardly be taken as paradigmatic of cognition in general: the cognitive apparatus evolved to cope with day-to-day needs and dangers. Rather than scientists' discoveries, it is the ability to solve problems present in the environment that determined the selection of the genetic basis of human psychology that is best likely to characterize the function of evolved cognitive abilities. The human brain, in particular, evolved when the human species was hunting and gathering, and our cognitive apparatus is therefore designed for coping with the tasks of the hunter-gatherer as performed in the manner of our ancestors. Science, on the other hand, is a very recent cultural achievement; science making cannot be a biological function of the human brain. The challenge for the evolutionary epistemologist is then to explain how scientific cognition is done with the means of a brain that evolved for hunting and gathering. Taking evolutionary psychology seriously requires that the theories of cognition—including scientific cognition—be compatible with some evolutionary history of the biological function of cognitive processes. Thinking of human evolved cognition, evolutionary psychologists such as Gerd Gigerenzer et al. have emphasized fastness and frugality, which provide obvious advantages in the face of natural selection (*Simple Heuristics*). Others have emphasized the domain specificity of cognitive processes, leading to the thesis that the mind is massively modular (Barkow et al.). In comparison, it is implausible that blind variation and selective retention evolved as domain-cognitive processes, on top of which "shortcuts," such as heuristics, would further evolve. Evolutionary psychology recenters the investigation of cognition on real-world tasks rather than on abstract problem solving (such as scientific theorization) because it requires assessing the adaptive behavior enabled by cognitive processes.[1]

Challenge Ahead: From Evolved to Scientific Cognition

From Ecological to Scientific Rationality

The assertion that the biological functions of cognitive processes are designed (through evolution) for coping with the environment (so as to ensure survival and reproduction) leads to the investigation of "ecological rationality" as a property of cognitive processes (Gigerenzer et al.).

Evolutionary epistemology, by its very definition, must be compatible with the above principles of evolutionary psychology. How can we pass from ecological rationality to scientific rationality? The latter is oriented towards the discovery of truth, while the former is oriented towards gains in fitness.[2] I suggest that key factors that lead from ecological rationality to scientific rationality are communication and the social aspects of knowledge making. The fact that communication and social interaction constitute essential parts of scientific practice is nearly a truism. Communicating new ideas and convincing peers of their truth are core activities of scientists. Scientists also constantly assess the truth or plausibility of what other scientists communicate.

The importance of communication in the social evolution of science is actually much present in Popper's epistemology. Commenting on Campbell's evolutionary epistemology, Popper emits a criticism, which he claims to be related to the difference between man and animal, and especially between human rationality or human science and animal knowledge ("Replies"). Popper stresses the argumentative practice that is at the heart of science and that makes criticism possible. In doing so, Popper points out that science is a social practice that involves people communicating and judging each others' communications. It is this fact that put the problem of truth and scientific rationality back into scientific cognition.

With regard to truth, Popper says: "I think that the first storyteller may have been the man who contributed to the rise of the idea of factual truth and falsity, and that out of this the ideal of truth developed; as did the argumentative use of language." The ideal of truth and the practice of argumentation therefore stem from social interactions; they are constitutive of scientific cognition because science is a social activity, with argumentation at its core (Mercier and Heintz, "The Place" and "Scientists"). On this basis, new constraints on scientific cognition arise: scientific cognition must conform to the rules of scientific rationality, which is made of historically developed normative ideas about truth-preserving cognitive processes. Through this complex path, going through social interaction, scientific cognition becomes rational in the normative sense, rather than ecologically rational. In Campbell's evolutionary accounts of the history of science, both individual cognition and social processes are given due roles, but not so as to account for the evolution of the factors of success of scientific ideas: the evolution of normative ideas about what it takes to be scientifically justified. The factors of selection of scientific ideas are immutable.

Campbell faces a dilemma. He can adopt the views of evolutionary psychology and assume that human cognition in general, and scientific cognition in particular, is ecologically rational. He then misses essential features of scientific cognition, which aims at truth and objectivity. Alternatively, he can adopt a scientific-centered view of human cognition. He then abandons the vow to be compatible with theories of man as the product of biological evolution. Putting communication, social interaction, and their cognitive bases at the center stage of the evolution of science should help solve the dilemma.

Scientific Creative Thinking from Massively Modular Minds

Another difficulty with relating evolved and scientific cognition comes from the apparent flexibility and creativity of scientific thinking. Evolved cognition, by contrast, seems not to allow for such features in human cognition: evolved cognition is constituted by a set of cognitive mechanisms that have evolved to deal with specific adaptive problems—modules. As evolutionary psychologists have hypothesized, the mind is massively modular. Fodor has argued that central cognition, in particular the processes issuing in belief formation, are not modular (*The Mind* and *The Modularity*). Fodor's arguments in *The Modularity of Thought* appeal to scientific cognition as the archetypical cognitive performance, which shows that belief formation relies on cognitive processes that can draw on any information held in the mind. Scientists, or so it seems to Fodor, have unrestricted access to their stored information, which could not be so if the human mind were massively modular. In spite of the difficulties it comes with, as those forcefully pointed out by Fodor, the massive modularity hypothesis remains the standard account of human evolved cognition among evolutionary psychologists. So the challenge is to show how a massive modular mind can be flexible enough to produce new scientific ideas.

Cognitive flexibility is defined as the ability to adapt cognitive processing strategies to face new and unexpected conditions in the environment. It involves learning how to deal with new types of problems by implementing new computations. These learning abilities and exploratory strategies seem not to be attainable with massively modular minds—which are composed of task-specific cognitive devices. The massive modularity hypothesis also imposes important constraints on the architecture of the mind and on the consequent flow of information: an input is processed by the modules to which it meets the input conditions, which produces an output acting as an input for further modules, depending on the architecture of the mind, until the processing comes to a halt. The communication between modules is relatively limited, and strongly constrained by the cognitive architecture.

How can we account, with this hypothesis, for the known flexibility, diversity, malleability, and creativity of human behavior? How can we account for the human ability to integrate information from different domains? It is a challenge that proponents of the massive modularity hypothesis have taken seriously. Sperber argues that flexibility and context sensitivity are attained, at the psychological level, because most modules are learning modules ("In Defense" and "Modularity"). Learning can happen not only through the enrichment of modules' databases but also through the fixation of parameters determining the domains of modules.

Development, according to Sperber, also includes learning that is reflected in modular architecture: learning modules produce dedicated modular subsystems for acquired capabilities. Last, in order to account for context sensitivity, Sperber argues that modules do not process inputs in a mandatory way ("Modularity"). One of Fodor's characteristics of modules is that once an input meets the input conditions of a module, the module is automatically triggered and runs its full course. Sperber argues on the contrary that a module is activated not just in view of its input condition, but also in view of the relevance of the input, that is, its expected cognitive effect (such as acquisition of new and useful information) and effort for processing it. Nested modularity, enrichment, maturation of cognitive abilities, development of new modules through learning, maximization of cognitive efficiency are features of the modular mind that provide much flexibility. How do they support scientific cognition?

Carruthers argues for a "moderately massive modularity" where the language module is given a special role serving as the medium of intermodular integration and conscious thinking ("Moderately"). Without denying the role of the above principles of flexibility, context sensitivity, and integration, I would like to emphasize the role of metarepresentations in generating new integrated knowledge, and sustaining conceptual change in science. The flexibility of the human mind, indeed, is paradigmatically exemplified with conceptual change in science, where some previously held beliefs are abandoned and replaced by new beliefs incommensurable with them. In particular, conceptual changes in science have rendered some of the content of science at odds with intuitive beliefs. How can we have come to think, and be now so convinced, that the earth is moving around the sun while the contrary belief naturally imposes itself upon us? While knowledge enrichment can be thought of as the addition of new data to previously existing databases, conceptual change and the abandonment of previously believed theories requires, on the part of scientists, a new attitude towards the stimuli of the newly theorized domain. What are the cognitive processes accounting for these new attitudes? The existence of conceptual change raises two questions for cognitive psychologists. First, what are the cognitive processes that make conceptual change possible? Much work has been done in cognitive studies of science on this topic. Most notably, Nersessian has analyzed the role of physical analogy, the construction of thought experiments, and limiting case analyses ("In the Theoretician"). Carey has also pointed out the role of mappings across cognitive domains for the creation of new domains (e.g., Carey, *Conceptual*; Carey and Spelke, "Domain-Specific"). There is general agreement that conceptual change involves metarepresentational abilities. Scientific cognition heavily relies on the ability to metarepresent our own representations, and thus to think reflectively. Metarepresentational ability allows for the processing, using, and producing of representations of representations. One or more cognitive modules may implement the ability. Some metarepresentational modules, indeed, have an already studied evolutionary history and satisfy the requirements of evolutionary plausibility. Presumably, metarepresentational abilities appear with the ability to represent the representations that others may hold—their mental state. This ability, called Theory Of Mind (TOM), is adaptive by allowing Machiavellian intelligence, the ability to manipulate others' behavior, and is certainly at the basis of human social life, including linguistic communication.

The relevant consequence of metarepresentational ability (or abilities) is that the cognitive output of modules can be rethought. In particular, metarepresentational abilities enable making epistemic evaluation of the output of modules. For instance, I perceive that the sun is traveling around the earth, but I know that this perception is misguiding. When a perceptive representation gets embedded within a framework theory, the perceptive representation is metarepresented as a manifestation or consequence of some state of the matter or of some laws of nature. Scientific practice, says Nancy Nersessian, "often involves extensive metacognitive reflections of scientists as they have evaluated, refined and extended representational, reasoning and communicative practices" ("The Cognitive" 135). Deana Kuhn has also pointed out the metacognitive skills at work in scientific thinking. These include not only metastrategic competence, but also the ability "to reflect on one's own theories as objects of cognition to an extent sufficient to recognize they could be wrong" (275). Metarepresentational abilities are thus central to scientific thinking. Most interestingly for our present purpose, they also bridge the gap between lower cognitive abilities processing the input from our sense organs, hardwired heuristics and naïve theories, and the abstract and consciously controlled thinking practices of science.[3] I therefore suggest that scientific thinking is well characterized as a systematic exploitation of human cognitive abilities by exploiting, via metarepresentations, existing heuristics and intuitions.

Spranzi's case study is an example of such reasoning, where an analogy is drawn between two distinct phenomena: Galileo interprets the black marks on the moon as similar to the shadows thrown by mountains on the earth ("Galilei"). Now, Spranzi argues, the analogy did not pop up out of the blue—which would have exemplified a mysterious "Fodorian" (isotropic) cognitive event. She shows, on the contrary, that it was rendered possible through a historical process of bootstrapping. In other words, the cultural context made some ideas and representations available to Galileo, making the analogy possible. We therefore have a case where the determination of scientific thinking is shown to be historical and social as well as cognitive.

Cognition does not only take place in a cultural environment: more radically, aspects of the environment itself implement or contribute to cognitive processing. For instance, Galileo perceived shadows on the moon by means of his telescope. As another instance, most scientists now perform their statistical analysis with specialized software or programming languages. Here is, therefore, another source of flexibility: scientific cognition is implemented in systems in which cognition is distributed to tools and specialists. These "distributed cognitive systems" quickly change; they have the plasticity out of which flexibility arises. In particular, new technologies are exploited, new experts are given new roles in the production of knowledge, and the architecture of the systems changes as a function of the available resources and goals. (For instance, contemporary large experiments in atomic physics require numerous researchers dealing with very specific tasks, while traditional theoretical debates require few researchers having similar expertise). This suggests that distributed cognitive systems evolve so as to respond to contextual factors such as changing means and needs. Flexible cognition is thus also achieved through the flexibility of institutions of scientific production and their associated systems of distributed cognition.

Conclusion on Evolutionary Epistemology and Scientific Innovation

An important gap in science studies is the study of the role of our primary intuitions in scientific knowledge (Heintz, "Scaffolding"). Social studies accord little importance to these cognitive events that are intuitions, while cognitive studies are much more focused on higher reasoning practices (induction, abduction, analogical reasoning, thought experiment, etc.). The continuity thesis, which asserts that scientific cognition is of the same nature as lay cognition, has raised important debates that could bear on the distinction and relation between reflexive and intuitive thinking, between metarepresented knowledge and the direct output of non-metarepresentational modules (see Sperber, "Intuitive," for the distinction between intuitive and reflective beliefs). In other words, Campbell set a research program that has not really been implemented. One possible reason was that Campbell himself skipped through it and appealed to blind variation instead, which we criticized as either being an implausible description of scientific cognition or a black box standing for the complex psychology of scientific innovation.

Selective Retention Does Not Adequately Describe Why Some Ideas and Practices Spread

According to the traditional view of evolutionary epistemology, blind variation that generates new ideas occurs within scientists' minds, while selective retention is mostly a social process involving scientists checking the work of others and choosing the best of it. Selective retention involves a process of selection that well describes the fact that not all of scientists' ideas gain the status of scientific knowledge and get distributed in the scientific community. But selective retention involves also a process of retention, and Darwinian selectionist theory holds that it is done through replication. In biology, it is DNA sequences that are replicated; in science, the replication is of beliefs, ideas, and practices. The replication happens by means of social interaction, mainly communication.

David Hull, whose work can be understood as a refinement and updating of evolutionary epistemology (*Science as a Process* and *Science and Selection*), specifies what replicators are in the evolution of science:

> the replicators in science are elements of the substantive content of science—beliefs about the goals of science, the proper ways to go about realizing these goals, problems and their possible solutions, modes of representation, accumulated data reports, and so on . . . These are the entities that get passed on in replication sequences in science. Included among the chief vehicles of transmission in conceptual replication are books, journals, computers, and of course human brains. As in biological evolution, each replication counts as a generation with respect to selection . . . Conceptual replicators interact with that portion of the natural world to which they ostensibly refer . . . only indirectly by means of scientists. (*Science and Selection* 116)

Conceptual replication is a matter of information being transmitted largely intact from physical vehicle to physical vehicle. The problem is that replication at the conceptual level does not properly describe the mechanisms through which representations are distributed and stabilized within a community. An appeal to replication is a way to black box the mechanisms of transmission. As the notion of blind variation, it prevents from developing studies that investigate actual cognitive processes and their evolved basis.

In order to make this point, I only briefly review the arguments put forward by Sperber and colleagues against selectionist models of cultural evolution (Heintz and Claidière; Sperber, *Explaining Culture*; Sperber and Claidière). The bulk of the argument is that representations do not in general replicate in the process of transmission, but rather they transform as a result of a constructive cognitive process.

In place of replication and selection, Sperber appeals to the role of several factors stabilizing the distributions of representations. Among those factors, importantly, lies the rich and universal human cognitive endowment. For instance, a natural language is known and distributed within a population not only because children learn to speak on the basis of what they hear, but also because they have an unlearned ability to learn languages. As Sperber and Cladière put it: "cultural propagation . . . is achieved through many different and independent mechanisms, none of which is central and none of which is a robust replication mechanism" (20). In particular, imitation is not the main mechanism of transmission, but only if "the notion is stretched to cover a wide variety of quite different processes" (20). Thus, the observed macrostability, as manifested by "relatively stable representations, practices and artifacts distributed across generations throughout a social group," (21) does not warrant the existence of mental processes insuring the microheritability of cultural items.

For instance, one can hear a version of the little red riding hood tale, where, say, it is not specified that the wolf is greedy and cunning. Yet, this aspect can easily be inferred from the behavior of the wolf. This inference is a constructive process that draws upon a disposition to ascribe intentions and psychological traits to agents. This inference will in turn influence how the tale will be told, again, on the basis of an understanding of what cunning and greedy people do. More generally, the utterances heard during the telling of a tale are interpreted. This is a constructive process that might rely on cognitive capacities shared by a community and that are psychological factors of attraction: they favor some interpretations more than others. The same holds for the transmission of mathematical proofs, and scientific theories and their empirical basis. For instance, many steps are being skipped in a written or uttered proof. Mathematicians in the audience just reconstruct these steps, sometimes automatically, and at other times after some effort. Background knowledge is key: no mental representation of the proof of Gödel's first incompleteness will be constructed if it is told to someone with no mathematical literacy. The proof of Gödel's first incompleteness theorem is not merely replicated. If it was so, its versions would quickly drift towards non sense. The proof is understood, which means that background knowledge and diverse cognitive processes are put to work for interpreting some written or oral version of the proof. This trivial observation demonstrate that transmission of scientific ideas and practices is not resulting from some domain general mechanism of replication, it is resulting from complex processes of understanding and communicating. Thus, "the microprocesses of cultural propagation are in good part constructive rather than preservative" (22). Consequently, Darwinian models of cultural evolution are unsatisfactory because "cultural contents are not replicated by one set of inheritance mechanisms and selected by another, disjoint set of environmental factors" (22).

Opening the black box that "retention" is around the multiple processes of cultural transmission, one sees that transformation is pervasive and faithful replication is a rare limiting case of zero transformation. Theories in psychology and sociology about memory, imitation, and communication show that high-fidelity reproduction is the exception rather than the rule. The consequence is that concepts or ideas are not replicated well enough to undergo effective selection: the rate of change is such that selection cannot be consequential on evolution. How, then, can ideas and practices, including scientific ones, form cultural phenomena?

The causes of preservation and propagation often lay in the fact that constructive biases are shared in a population. I mentioned the universal human cognitive endowment, such as the ability to communicate, but, importantly, similar aspects in individuals' histories also cause shared constructive biases, such as the knowledge and practice of a scientific paradigm, which provides an interpretative framework for processing new input. In spite of the fact that transmitted representations are different from one another, the representations do not drift away through added transformations to strongly dissimilar representations. The constructed representations tend to gather around some "attractors." For instance, the mental representations of a proof do not resemble in any straightforward way to the public representations, yet they resemble each other's in relevant ways: they cluster around a perfect understanding of the proof. They will give rise to public versions of the proof which, again thanks to shared constructive mechanisms (including communicative skills), will tend to cluster around understandable versions of the proof.

The Darwinian selectionist model for thinking about the evolution of science is certainly a source of inspiration and discovery. Hull, for instance, draws on the model for explaining social processes of competition and collaboration in the sciences (*Science and Selection*). In the same way as inclusive fitness in biological evolution accounts for kinship altruism, in the sciences, scientists promote both their own work and the work of those who use their work. The works of scientists thus have "conceptual inclusive fitness." However, the Darwinian selectionist model makes erroneous assumptions about scientific cognition. Assuming that one single mechanism enables the faithful transmission of scientific ideas hinders rather than fosters the cognitive and social investigation of the processes of cultural evolution.

The criticism against selective retention as a process of scientific development can be summed up with the following points:

1. As opposed to biological evolution, there is no mechanism of replication that would insure the faithful copying of ideas and practices. Cultural transmission is realized by diverse processes that are implemented in evolved psychological mechanism, but also by learned skills, artifacts, and institutions.
2. The mechanisms of cultural transmission are not especially preservative processes. Processes of transmission involve transformations, and preservation is only a limiting case of no transformation.
3. The consequence of the above lack of faithful transmission is such that there is not enough retention for selection to operate on stable populations of cultural items.
4. Ideas and practices are maintained and spread not through faithful replication, but through attraction: transmission induces some transformation, but these transformations are systematically biased towards an "attractor." Cultural phenomena are made of clusters of resembling tokens rather than identical tokens.
5. The above points, made by cultural attraction theorists for understanding the evolution of culture in general, apply to the cultural phenomena that constitute the history of science and technology. The transmissions of scientific ideas and practices are complex processes relying on multiple mechanisms whose function is not replication. Transmission events need not be faithful and preservative. If and when they are, this needs to

be explained rather than granted. The success of an idea or a practice can be explained by attraction rather than just retention.

Challenge Ahead: The Stabilization of Scientific Beliefs and Practices

Science as Cumulated Culture

How can we obtain the stabilization of some specific ideas and practices in spite of the fact that cultural transmission is not sufficiently faithful? The hypothesis put forward by cultural attraction theory (also called cultural epidemiology; Heintz, "Cultural Attraction Theory"; Sperber, *Explaining*) is that some forms or types of ideas and practices are more likely to be produced than others. The cause of stabilization thus does not rely on the viability of transmission processes, but on the constructive processes that, in spite of small variations in input, are likely to produce outputs that resemble one another.

How can cultural attraction theory be used for explaining the stabilization of scientific beliefs and practices? It has been put to work for explaining the spread of intuitive and minimally counterintuitive beliefs: pseudoscientific beliefs (Blancke et al.; Miton et al.) and religious beliefs (Boyer), for instance. Practices of painters (Morin) have also been analyzed with cultural attraction theory.

Yet, while this type of account acknowledges the role of evolved cognitive capacities in shaping cultural phenomena, it does not seem to provide a proper framework for understanding the cumulated culture that characterizes science and technology. Explaining scientific beliefs and practices seems to raise another type of challenge because it seems so disconnected from our naive or intuitive beliefs. Some of our scientific beliefs are even downright counterintuitive (e.g., Darwinian evolution; see Atran; Gervais). Science results from a cumulative process that seems to make evolved intuitions irrelevant to understanding the history of its content. Doesn't scientific cognition stand on reason rather than evolved intuitions? The question about how to go from ecological rationality to scientific rationality arises here again, which is not surprising, since the processes of variation and retention are not essentially distinct. However, what is of special interest for this subsection is how acquired knowledge and cognitive skills become constructive mechanisms at work in the transmission of complex scientific ideas and practices.

More precisely, the cumulated aspect of cultural evolution can be grasped by considering the following:

- The input of psychological mechanisms is, most of the time, itself a socially constructed input. Currently, many of the things we perceive and that affect cognition have been anteriorly processed by humans: these include linguistic productions, of course, and human artifacts. Even when scientists study basic natural phenomena, such as the behavior of atoms, the input they use for theorizing about them involve many cultural artifacts: it is, for instance, a data chart produced by a computer after some highly controlled experiment happened. This is vividly illustrated by the activity of scientists at the CERN, who study fundamental natural phenomena but in a highly constructed social and material environment.
- Psychological constructive mechanisms are themselves the result of cultural processes. Both genetic endowment and individual history determine an individual's psychology. While evolutionary epistemology prompts us to pay special attention to evolved cognitive mechanisms, this cannot be sufficient for understanding how highly enculturated individuals think—including scientists, who benefited from a long and complex education, most of the time by way of educational institutions (and, rarely, through the sole access to scientific writings).

These are simple and, I would say, noncontroversial observations. Yet, they point to the relevance of a multiplicity of processes, and it is a challenge to integrate them in a single evolutionary account. Constructive processes at work in the transmission of scientific ideas involve "cognitive artifacts" and "learned skills" as well as evolved intuitions.

There is a fuzzy and changing set of common beliefs that regulate scientific practices. These beliefs have been sometimes characterized as epistemic claims about the value of empirical investigation, the use of mathematics, the avoidance of ad hominem arguments, and other values coming from the scientific revolution (Shapin). These shared beliefs contribute to generating types of behaviors because they are "scientific," and these behaviors stabilize in the scientific community for the same reason—being considered as scientific by the scientific community. Fuzzy subsets of common beliefs can be found at the more local levels of disciplines and research fields. The sets will include implicit and explicit beliefs, know-how and know-that, beliefs about the reliability of some instruments, beliefs about nature, and beliefs about methods of investigation. The role of education cannot be overemphasized in science: it includes memorization, but also drills of scientific practices. It importantly contributes to building shared cognitive capacities among scientific communities. These shared capacities will be involved in the construction of mental representations and public productions.

Scaffolded Attraction in the Making of Science

The important consequence of the above observations for cultural attraction theory is that factors of attraction, while they do influence cultural evolution, can themselves be contingent on historical and cultural phenomena. For instance, scientific education includes a specification of the problems worth solving and the kinds of tools that might be useful for the task: such specifications are factors of attraction because they determine what will interest scientists and how they will dedicate their efforts. But these factors of attraction are not evolved; they are themselves the product of history. Education and, more generally, enculturation will partially determine what attraction there will be. Likewise, the material environment—what kind of facilities there are, the social environment—and who talks with whom will also partially determine the content and form of cultural attractors. Enculturation and the cultural environment (material or social) constitute scaffolds for cultural attractors.[4] There is cognitive attraction caused by evolved cognition, but also scaffolded attraction caused by learned skills, knowledge, habits, and the historically built environment. The more specific challenge for evolutionary epistemology is to specify the scaffolds that are important factors of attraction in science. The cumulative aspect of science is partially expressed by the fact that there is scaffolded attraction. For instance, the success of calculus in the eighteenth century is due to the fact that it helped solving already well-known and well-specified problems: for instance, calculating an area under a curve was a well-known problem well-specified in Cartesian geometry, and calculating the speed and acceleration were problems whose importance derived from Galileo's work. In that sense, preliminary geometric and mechanistic knowledge specified ways of using calculus. The preliminary knowledge did therefore more than just enable the discovery of calculus: it is not just Newton who had to climb on the shoulders of giants, but his readers too. And it did more than just make calculus useful (increasing its cultural fitness, in Darwinian selectionist theorization): it acted as a factor of attraction towards some mathematical practices.

There are, among the ideas shared by the scientific community, normative ideas that regulate how other ideas should be produced. For instance, in many research fields, standard thought is that only experiments that show a statistical significance (a low p-value) are worth being published.[5] These normative ideas do play a role in scientific practices. In our example, experiments will be designed so that a significant difference between experimental conditions might be revealed. They also play a role in the success of ideas or representations. In our example, only papers showing a p-value lower than .05 will be published in prestigious journals. An important argument made by sociologists of science (e.g., Barnes et al.) is that all scientific ideas and practices have such a normative aspect because science is essentially a social product that involves social interactions and coordination. For instance, a scientific term includes a normative component about how it should be used: the kind of inferences it warrants, how it relates to other scientific or nonscientific terms, and its reference. There is therefore a social regulation of the use of scientific terms that will impact the interpretation and production of these terms. Such norms are also scaffolds that strongly regulate the production of representations.

The constructed material environment can also act as scaffolded attraction. The role of material tokens in science making is apparent with writing, which has been the main means for sharing beliefs and thus establishing common grounds. The pervasive reference to written artifacts obviously constrains scientific thinking: written artifacts provide to scientists a shared corpus of data, of theoretical and methodological texts. Materials in science also include cognitive tools, such as the telescope or, more recently, data-crunching computers. And they include material models of natural phenomena; for instance, the physical models of molecular structures are a research tool that has influenced the thoughts and productions of chemists (Charbonneau). The general aspect of such models is that once their cognitive role is being specified, they fully participate in the production of knowledge. Again, we have shared elements that participate in the production of mental representations and public productions. These shared elements increase the probability that some cultural items rather than others will be produced. They act as scaffolding factors of attraction. Another way to put it is that the cognitive constructive processes that will act as factors of attraction not only are in the heads of scientists but are systems that include scientists and their cognitive tools. The work on distributed cognitive systems in science (Giere and Moffatt; Nersessian et al.) is relevant to understanding the factors of attraction in the history of science.

Conclusion on Evolutionary Epistemology and Cultural Attraction Theory

The selectionist evolutionary model does appear to provide solutions to the challenge of explaining cumulated culture. Cultural items are usually faithfully copied, but sometimes, one of the relatively rare mutations turns out to be more successful than other variants. The success of a variant is mainly (but not only) determined by its ability to confront the world whose selection pressures occur in the form of experimental tests. As ideas confront the world through new experiments, some are refuted and selected out and others survive. As appealing as it is, this picture is a simplification that historians of science are not willing to use for describing scientific developments. It prevents from discovering the true underlying processes that spread ideas and practices in a community.

Rather than appealing to selective retention, I think the best way to pursue the program of evolutionary epistemology is to use cultural attraction theory. This move enables relaxing the assumption that selection is the only factor accounting for the stabilization of some ideas and practices. It also advocates peering into the constructive processes that will act as factors of attraction, which make some ideas more stable than others in spite of important changes occurring in the chains of transmission.

The main advantage of relaxing the assumption of Darwinian selection is that it reopens evolutionary epistemology to all the work that has been done by sociologists, historians, and cognitive scientists of science. I have alluded to the Khunian notion of paradigm and its development when talking of the fuzzy set of ideas and practices that are shared by the research community, I have pointed to the work of sociologists on the conventions and social norms that are pervasive in science making, and I have made reference to the work on distributed cognition as an important addition for describing the cognitive constructive mechanisms of scientific production. Cultural attraction theory does not provide an alternative explanation to the constructive processes of science making. It only provides a framework for connecting the evolutionary aspect of science, as a cultural domain, to the social and cognitive events described in science studies.

In the end, it might turn out that science is the most selectionist of the evolving cultural domains. But this should be explained, not just assumed. Selection might be due to specific institutions: the educational system, the systematic reliance on writing, the relative perennity of material arrangements—these all make reproduction more faithful. There are also institutions that implement the selection of ideas: in particular, the system of scientific publication and the argumentative practices that encourage systematic skepticism.

What of evolved cognitive capacities? While their role has been pointed out above, they have disappeared in the current section. In fact, my bet is that when describing the scaffolded factors of attraction, one will eventually see that they are grounded in evolved cognitive capacities. For instance, teaching institutions will be more successful in their teaching if they rely on existing learning capacities. More radically, I have argued elsewhere that the interpretation of even complex mathematical notions is geared by evolved cognitive capacities (Heintz, "Scaffolding").[6]

Conclusion

Campbell's ambition to find a unique principle accounting for biological evolution, cognition, and scientific evolution provides an oversimplified picture of cognition and culture. The naturalization of science studies passes first through an integration of cognitive and social studies of science. Imposing the Darwinist selectionist model on the evolution of science leads to bypassing too much of the results in cognitive psychology and the sociology of science.

The sociology and history of science of these last decades have pointed out the social processes at work in scientific knowledge production. These include the institutional constitution of science, the coercive strength of scientific traditions (including the norms of rationality), the self-referring aspects of scientific beliefs, the goal orientation of research, the role of trust in science, novice-expert interactions and how scientific practices are taught and learned, the reliance on external values and beliefs, and negotiations during scientific controversies. The abstract and methodological Popperian picture of conjecture and refutation is given more sociological reality, which implicates a complexification that can no longer be grasped with blind variation and selective retention. Blind variation and selective retention seem, at this stage of sociological and psychological knowledge, unable to account for the factors determining the success of scientific practices, including scientific judgments; the forms of justifications, rebuttal, and assent; types of scientific communication; and the causes of creative thinking.

Still, evolutionary epistemology is a worthwhile project for two reasons. First, it stands on a naturalistic ontology; there are beliefs and behavior. Some beliefs stabilize in the scientific community and others do not; some behaviors become common practices and others do not. This ontology comes with a research program: specifying what more holistic notions, such as "paradigm," really mean and, more generally, analyzing cultural phenomena in terms of the spread of ideas and practices in a community. Second, evolutionary epistemology requires understanding scientific knowledge production as the activity of evolved organisms—the scientists. Evolutionary psychology is thus made relevant to understanding the history of science. This, again, comes with a research program, which consists of specifying the role of evolved capacities in scientific practices and thinking.

These two related research programs have known few developments as such, but contemporary work in the history and sociology of science and work on scientific cognition are already contributions to these research programs. Evolutionary epistemology as I advocate it is thus not much more than a comprehensive framework that emphasizes the relevance of interdisciplinary investigations—psychology, sociology, and the history of science—and enables spelling out the contribution of one to the other. Evolutionary epistemology in the restrictive sense, as envisaged by Campbell and pursued by Hull, by contrast, relies on the assumption that culture evolves and knowledge is produced by means of blind variation and selective retention. I have argued that this assumption is not well grounded and furthermore prevents investigating the constructive processes through which culture and knowledge are produced and spread. I therefore advocate doing evolutionary epistemology, but only in the nonrestricted sense of the term. In the place of blind variation and selective retention, I have argued that cultural attraction is what enables the stabilization of cultural items. To understand cultural attraction, one needs to discover the constructive processes that generate new ideas and their interpretations by the scientific community.

Notes

1. To be fair, Simonton's account of creativity is compatible with Campbell's idea of cognition as blind variation and selective retention ("Creativity"). Simonton states that hypothesis formation is based on a subconscious random generation of ideas: only selected ideas come to consciousness, but a massive number of unconscious random ideas have been previously generated. However, such a process has low adaptive value because it requires computing a massive number of ideas. In addition to its low adaptiveness (the generation of a massive number of random ideas seems too costly for being selected by natural evolution), there is little empirical evidence in favor of a hidden, unconscious, chaotic generation of ideas (Sternberg).
2. For a radical analysis of the difference between truth-preserving cognitive mechanisms and fitness enhancing ones, see Stich, *The Fragmentation*.
3. Gorman, "Heuristics," illustrates this point with Kepler's mental model of the solar system and the application of heuristics as designed and implemented in the discovery program, BACON 1, of Herbert Simon and his colleagues. Kepler's particular problem representation, he explains, was necessary for the heuristics to apply and be useful.

4. I take the term "scaffolding" in cultural evolution from Wimsatt and Griesemer, "Entrenchment" and "Reproducing," and their analysis of cumulative cultural evolution.
5. The dominant role of the p-value is currently being challenged, with Bayesian data analysis as a competitor statistical method (Gelman et al.).
6. The case study (Heintz, *Cognition*) consisted of showing that the interpretation of the notion of infinitesimal was influenced by our object-tracking systems, which Susan Carey has shown to be involved in learning natural numbers ("Precis"; Carey and Spelke, "Science").

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Chapter 12

Intuitions in Science Education and the Public Understanding of Science

Stefaan Blancke, Koen B. Tanghe, and Johan Braeckman

Abstract

Although science builds on ordinary, intuitive reasoning, its results can be highly counterintuitive. This tension between the intuitive, cognitive basis of science and its counterintuitive results offers both opportunities and challenges for those who are involved with taking science to the public, in particular science educators, communicators, and popularizers. On the one hand, they need to engage with people's intuitive understanding by resorting to appealing metaphors, imagery, or narratives as tools to facilitate the understanding and acceptance of scientific concepts. Because of their intuitive appeal, these representations can become popular, bringing scientific concepts to large parts of the public. On the other hand, however, these tools can also be highly misleading, creating or sustaining unscientific representations that, because of their intuitively appealing nature, are more likely to become popular within the culture at large than the underlying scientific concepts the educator or communicator is trying to convey. Furthermore, as science educators, communicators and popularizers do not have minds that differ markedly from any ordinary human mind, they themselves are not entirely immune to the powerful seduction of intuitively appealing representations, thus enforcing their misleading effect. As such, science educators, communicators, and popularizers should be careful about the educational, communicational, and rhetorical strategies and tools they employ. Some can become highly

successful, but this might come at the expense of their own understanding of science and, especially, that of their audience and of society at large.

Scientific Thinking as Scaffolded Cognition

Traditionally, the philosophy of science looked at science in the abstract. Philosophers assumed that they could get at the nature of science by treating it as a collection of symbols that stood in a special formal relationship to both one another and the facts of the world. The task of the philosopher was to apply the tools of logic to lay bare these relations. The assumption was that science or the scientific method produced a special and solid type of knowledge, one that was rooted in deduction and pure induction, characterized by rational ways of reasoning and, above all, blessed by steady if largely piecemeal progress. However, this research program failed, and for good reason. Philosophers generally found that there yawns a wide gap between their models of rationality and progress and the actual process of science, whereas sociologists and historians brought to light several irrational or not so rational factors and forces in concrete cases or episodes of scientific change. Karl Popper in a way still tried to salvage the traditional, rational model of scientific progress by invoking an idealized, dialectical process of conjecture (of scientific hypotheses and theories) and refutation (or falsification) (Haack, *Defending Science*; Kitcher, *The Advancement*). It was Thomas Kuhn who showed that such ideal views on science in no way reflect actual scientific practice (*The Structure*). Science, as perceived and portrayed by Kuhn, is not about following the logical norms of induction and deduction, but about what real scientists do while trying to solve problems or puzzles under the guidance of a so-called paradigm or disciplinary matrix. One important aspect or dimension of this scientific praxis is that scientists do not work in isolation, but within social groups that can be described as cultures of science: the social nature of the scientific endeavor can hardly be underestimated (Goldman, *Knowledge*; Boudry and Pigliucci, this volume).

Several strands can be discerned in the post-Kuhnian philosophy of science. One approach focuses on its sociological aspects, and assumes that, given the failure of the traditional view, objective knowledge about the world is simply impossible. Hence, science cannot be considered a quest for objective truth, but is nothing more than sociological interactions based on power relations. Such ideas led to the development of relativism, postmodernism, and the science wars. The other approach, naturalism, accepts the idea of science in the flesh without, however, resorting to, or harboring, relativist ideas about that all too human endeavor. Instead, philosophers in the natural tradition assume, inspired by modern evolutionary theory, that scientific reasoning can and should be regarded as an activity of evolved, biological information-processing organs—human brains—that shape and constrain the ways scientists can obtain scientific knowledge about the world (Haack, *Defending Science*). As Phillip Kitcher writes:

> Science is not done by logically omniscient lone knowers but by biological systems with certain kinds of capacities and limitations. At the most fine-grained level, scientific change involves modifications of the cognitive states of limited biological systems. What are the characteristics of these systems? What kinds of cognitive states can they be in? What are their limitations? What types of transitions among their states are possible? What types are debarred? What kinds of goals and interests do these systems have? (Kitcher, *The Advancement* 59)

An important feature of this naturalistic approach is that scientific cognition is considered not to be fundamentally different from ordinary cognition. As Susan Haack puts it: "Scientific inquiry is continuous with everyday empirical inquiry—only more so" (*Defending Science* 94). This "continuity hypothesis" has paved the way for applying the methods of the cognitive sciences to the study of science itself, the results of which feed back into the research on human cognition (Nersessian, *Creating*). It also entails that philosophers of science need to be informed about the results of the cognitive sciences.

One of the main findings in cognitive science is that, in contrast to personal experience, human thinking is not limited to the mental processes over which we have voluntary control. Theoretical considerations within the field of artificial intelligence research, the cognitive sciences, evolutionary psychology, and a plethora of empirical studies have demonstrated that our thinking depends on domain-specific mechanisms that work largely under the radar of conscious awareness (Barrett, *The Shape of Thought*; Pinker, *How the Mind Works*; Tooby and Cosmides, "The Biological Foundations"). These evolved mental mechanisms provide quick and adequate solutions and responses to particular challenges, resulting in intuitive beliefs (Kahneman, *Thinking, Fast and Slow*). Luckily, we also have metarepresentational capacities that enable us to evaluate these intuitive beliefs (Kahneman, *Thinking, Fast and Slow*). Our intuitions do, in the form of systematic constraints, patterns, preferences, and biases, exert great influence on the resulting beliefs about beliefs or "reflective beliefs" (Mercier and Sperber, "Intuitive"). Nevertheless, in the course of our evolution and history, we have succeeded in overcoming the limitations of that intuitive reasoning and thus developed increasingly complex ways of living and thinking.

It is tempting to associate science exclusively with our reflective capabilities. Indeed, that is precisely the approach of the classic or standard pre-Kuhnian model. Certainly, scientists have to think hard and carefully about formulating their research hypotheses, setting up their experiments, making their analyses, and drawing their conclusions. They have to be aware of the distorting influence of perceptual, cognitive, and other biases. However, intuitive cognition plays an important part in science as well: not merely in the sense that our intuitions lead to hard-to-overcome biases, but also, and more importantly, that they enable us to reason scientifically at all. Indeed, recent cognitive approaches to science have discussed the roles of both types of cognition, the interaction between them, and their respective contribution to scientific thinking (Atran, *Cognitive Foundations*; Blancke et al., "From Ends to Causes"; Carruthers et al., *The Cognitive Basis*; Evans, this volume; Mercier and Heintz, "Scientists"; Mercier and Heintz, "The Place"; Nersessian, *Creating*; Thagard, *The Cognitive Science*).

This, however, confronts us with a paradox: if science indeed is based on, or inspired by, a natural way of knowing, how then, can it generate highly counter-intuitive results, that is, ideas and concepts that do not come naturally to mind? The solution lies in what is known as mental scaffolding (Heintz, "Scaffolding"). Scientists have managed to supersede the constraints they too have been endowed with by evolution. Mathematics, logic, and statistics discipline their reasoning and increasingly sophisticated artifacts render their experiments and observations more precise and support their cognitive processes; scientists rely on colleagues to check whether their ideas and results really match reality or express bias; analogies, models, and thought experiments enable them to explore uncharted domains on the basis of familiar, intuitive inferences and natural capacities. As such, human cognition has become extended, distributed, and social; in short, scaffolded (Sterelny, "Minds").

The Influence of Intuitions on Scientific Thinking

Intuitions as Biases

Because we are here primarily interested in intuitions, let us zoom in on them and elucidate their role in scientific thinking. Broadly, one can identify two types of influence. First, as intuitions entail naive assumptions about how the world functions, they often produce systematic distortions of, and even resistance to, scientific concepts and theories. Examples in the history of science abound. When in July 1837, Darwin scrabbled his first sketch of common descent in one of his notebooks, the image he produced looked like a piece of a coral reef. More than forty years later, however, Ernst Haeckel, German's foremost Darwinian in the nineteenth century, depicted evolution as a tree that ends with the emergence of man. He had transformed a widely diverging process without any specific direction into a purposeful progression. Such teleological representations of evolution are still popular today; think, for instance, of the chimp-like creature that gradually changes into a modern human. However, in contrast with Darwin's earliest drawing, these conceptions are not scientifically accurate, but rather reflect a strong tendency to ascribe a finalistic (and anthropocentric) purpose to natural events. This universal inclination, aptly coined "promiscuous teleology" by psychologist Deborah Kelemen, exerts, from a very young age, a strong influence on our thinking about the natural world (Kelemen, "Function"). When five-year-olds are asked why rocks are pointy, they prefer the answer that explains this property in terms of purposes rather than the answer that refers to natural causes. They believe that rocks are pointy "so that animals wouldn't sit on them" (Kelemen, "Why are Rocks"). With years of education, we learn to override the nefarious impact of our teleological reasoning—although we should immediately point out that this kind of thinking is not necessarily wrong: artifacts and, according to some philosophers, adaptations are perfectly explainable in terms of the function they serve (Ruse, *Darwin*; Kampourakis, *Understanding*). However, this does not completely immunize us against the siren song of teleological reasoning. Under speeded conditions, not only educated adults, but even professional scientists show a preference for teleological over causal-mechanistic explanations (Kelemen and Rosset, "The Human Function"; Kelemen et al., "Professional"). It is therefore unsurprising that scientists such as Haeckel also succumb to the allure of purposeful reasoning.

Haeckel's tree is but one example of the many misconceptions and representations of the evolution of life that emerged after the publication of Darwin's *On the Origin*. Historian Peter Bowler has documented how Darwin succeeded in making the idea of evolution acceptable in the scientific world, but failed to convince the majority of his colleagues of the mechanism of natural selection (*The Eclipse*). This period in the history of science is known as the eclipse of Darwinism. Scientists resorted to representations of evolution that somehow opened up space for the idea of purpose and even agency. In other words, they created, and argued for, types of evolution, such as orthogenesis and neo-Lamarckism, that aligned more closely with an intuitive understanding of the world. Perhaps the clearest example of a more intuitive representation of evolution is theistic evolutionism, which assumed that God guided and even actively intervened in evolution. One way, for instance, proposed by Asa Gray, Darwin's friend and leading Darwinian in the United States, was that God procured the right mutations so that organisms could adapt to their environment. This theory is highly intuitive for the same reason that religious beliefs are intuitive. It taps into our folk psychology. The mental capacity ("theory of mind") by which we spontaneously interpret other people's behavior in terms of mental states such as intentions, wishes, fears, emotions, and so on, evolved as an adaptation that facilitated living in ever bigger and more complex and tight-knit social groups. However, we also apply this kind of reasoning to purely natural things, processes, and phenomena or even to cultural artifacts. We kick the flat tire of our car because it ruins our plans for a trip to the countryside and curse our computer when it breaks down the moment we are about to finish our paper. Of course, we know that cars and computers do not have minds, but it is remarkable how readily we treat them as intentional beings. We also ascribe mental states to the biological world or describe and interpret it in terms of intentions and goals. Creation stories across the world imagine the origin of the world and life on it as the result of an intentional act by some powerful agent. Even in more secular surroundings, the intuitive idea that nature is designed for a purpose does not all of a sudden disappear from our thought processes (Evans, "Emergence"). Instead, it re-emerges as the idea of Mother Nature or (the strong version) of the Gaia theory, the belief that natural processes are intentionally designed to produce only good results (Järnefelt et al., "The Divided Mind"; Järnefelt, this volume).

Darwin himself contributed to the misunderstanding of his theory through his choice of metaphor. To explain the evolutionary process he had discovered, he relied upon an analogy with artificial selection. Just as breeders picked from the variation at hand in each generation the traits they were looking for, the environment "selects" those traits that add to the fitness of organisms. Hence, Darwin spoke of natural selection. However, by using the term "selection," he not only created an analogy, but also a metaphor that transferred the inferences that come with intentional thinking—that is, our folk psychology—onto people's thinking about evolution. As a result, people came to think of natural selection, not as purely natural, but as an agential process in which nature chooses the most suitable individuals or species and thus creates the diversity and complexity of nature. In fact, Darwin himself used the metaphor in exactly such a way when, for instance, he wrote:

> It may be said that natural selection is daily and hourly scrutinising, throughout the world, every variation, even the slightest; rejecting that which is bad, preserving and adding up all that is good; silently and insensibly working,

> whenever and wherever opportunity offers, at the improvement of each organic being in relation to its organic and inorganic conditions of life. (*On the Origin* 82)

The codiscoverer of the theory of evolution by natural selection, Alfred Russel Wallace, complained to Darwin that by employing such language he had misguided his audience. Darwin, however, was confident that, with time, people would understand his theory correctly. Given what we know today about people's predisposition to reason in intentional terms about natural events, it seems that Wallace had a point. By using an intentional metaphor to explain a natural process, Darwin triggered and strengthened rather than overcame people's intuitive thinking about nature (see Blancke et al., "From Ends to Causes," for a similar analysis of cladograms; Shtulman, this volume).

From an educational and communicational point of view, the metaphor is not always successful. It can realize the very goal it was intended to avoid, namely, that people think about the natural process of evolution in intentional terms. Nonetheless, from a cognitive perspective, it is understandable why Darwin chose this particular metaphor. Darwin's cognitive makeup was not basically different from anyone else's in that he shared the same predispositions as his contemporaries and these had been entrenched by the cultural environment he grew up in. Indeed, before Darwin left on his five-year voyage with the Beagle (1831–1836), he was a creationist. A series of observations and theoretical insights during his journey planted seeds of doubt about the traditional, theistic account of the origin of species that later developed into the mechanistic Darwinian theory of evolution. But in order to arrive at his radically new and counterintuitive way of thinking about nature, Darwin too had to override his intuitive inclinations. The analogy with artificial selection, with its intentional overtones, may have served to accomplish this difficult task, as it allowed him to reason about the terrain he was exploring in familiar terms, as if natural selection was an agent. In a way, he used a novel but still intuitive way of thinking (selection) to override another intuitive but traditional (creationist) way of thinking about nature.

Intuitions as Scaffolds

This story of natural selection brings us straight to the second role of intuitions in scientific thinking. Not only do they entail biases that hinder scientists in their quest for a better understanding of the world, they also function as scaffolds to attain such an understanding. Just as we depend on artifacts, rules of logic, and conspecifics to transcend our intuitive grasp of the world, we rely on our intuitions as building blocks to develop scientific knowledge (Heintz, "Scaffolding"). This is possible because intuitions not only process the type of information they evolved to process, but also any relevant piece of information that meets their input conditions. For instance, we have a face recognition system that responds to the presence of actual faces, but also to any cue in the environment that sufficiently resembles a face, from a realistic portrait or a photograph to a smiley (Sperber, *Explaining;* on the implications for the cultural evolution of portrait paintings, see Morin, "How Portraits"). Similarly, intuitive ways of thinking that generate our naive understanding of the world can be put to work on tasks they were not evolved to solve. The key thus lies in creating and providing the right cognitive environment so that our intuitions do not merely produce naive theories about the world, but scientific ones as well (for an account of the psychological faculties required for the transgression of our intuitive views, see Vlerick, "How Can Human Beings").

Such a perspective has considerable implications for our understanding of the development of science. The history of science shows that the scientific process does not merely constitute a simple and incremental accumulation of knowledge, but is characterized by deep conceptual changes (Vosniadou, *International Handbook*). The Darwinian revolution, for instance, was not simply an addition to the then extant knowledge about nature, but brought an entirely new way of looking at nature. Einstein's relativity theory and quantum mechanics depart sharply from Newtonian physics, which, in turn, contradicted even more intuitive Aristotelian physics. Such drastic changes in our understanding of the world could be easily interpreted in terms of replacing intuitive, but misleading, with counterintuitive, but more accurate beliefs, the latter being the result of reflective thinking. In this view, intuitions are overruled and replaced by a different type of reasoning. However, if intuitions remain at play even in scientific thinking, conceptual change is not a matter of replacing one way of thinking with another one, but of altering the ways in which intuitions function. Scientific thinking is not about fighting the impact of our intuitive reasoning, but about putting it to good use. We already mentioned, for instance, that teleological thinking is not bad per se. It helps us to think correctly about artifacts (that are definitely made for a purpose) and adaptations (that have been shaped by evolution to perform a particular purpose). However, it goes awry if we apply the same way of thinking to whole organisms (lions are to live in a zoo) and natural objects and events (rain falls to water plants). It also misleads us if we think that the function of an adaptation suffices to explain its existence: for instance, eyes have not come into existence with the purpose of giving us sight as natural theologians argued.

Instead, natural selection favored those mutations, which happened to enable our ancestors to make sense of light information, which gave them a bonus in terms of fitness. Teleological reasoning does not need to be eradicated from our thought processes (which would be impossible in the first place); it only has to be canalized and sanitized so that it enables us to attain a scientific understanding of the world (see Evans, this volume, for a similar argument and demonstration).

Another example of a hard-wired intuition that needs to be recruited properly is psychological essentialism. This is the spontaneous assumption that organisms contain an invisible and immutable core ("essence") that determines their identity, development, and behavior. As such, it poses serious obstacles to a scientific understanding of the biological world. Essentialist reasoning, for example, hampers a proper understanding and acceptance of evolutionary theory at several levels. For starters, it leads one to assume sharp boundaries between species and to disregard the individual variety that natural selection necessarily works on (Gelman and Rhodes, "Two-Thousand Years"). Even when students accept the concept of evolution, they tend to represent it in terms of changes of the species essence, rather than as the gradual rearrangement of properties within a particular population by natural selection (Shtulman and Schulz, "The Relation"). It also affects our understanding of genetics, as it makes us conceive of an organism's DNA as its essence. This becomes clear, for instance, in the context of the opposition to genetically modified organisms (GMOs). In one survey, when asked whether a tomato of which the genome was edited with fish DNA would taste like fish, not even half of the respondents gave the correct, negative answer. Moreover, people particularly oppose the practice when biotechnologists cross so-called species boundaries. They think it more problematic that an apple's genome would be engineered with DNA from a fish than from another race of apples (Blancke et al., "Fatal Attraction"). However, despite the fact that essentialism constitutes an enormous impediment to the understanding and acceptance of scientific theories and important technological innovations, it is not completely off the mark either. As in the case of teleological thinking, essentialism does capture several real properties of the biological world: organisms can indeed be categorized into different species. In fact, the idea that information of one typical member of a species can be extended to all members of that species forms the basis of biological studies (Shtulman and Calabi, "Cognitive Constraints"). And DNA does play a determinative part in the identity, development, and behavior of an organism. It is only when essentialism supports the belief in the fixity of species, in sudden mutations of species (to another "essence"), or the idea that a single piece of DNA contains the essence of an organism, that this intuitive way of thinking about nature distracts us. Again, whether or not essentialism has a negative impact depends on how the intuition is canalized (see also Evans, this volume).

One way to canalize intuitions in the right direction is the (correct) use of analogy. Analogies map the inferential structure of a familiar source domain unto an unfamiliar target domain, which makes it possible to fruitfully explore the unknown territory or to convey new insights with relative ease. Think of Darwin's selection analogy, which allowed him to understand and convey how nature generates adaptive biological structures and, eventually, new species. In this example, the immediate source domain is of course a cultural practice, but intuitions too can function as a source. In fact, intuitions can be considered to be inference machines that quickly and automatically provide us with enormous amounts of information without us having to store and consciously retrieve that information. Take essentialism, for instance. If one happens upon a woodpecker during a hike, it suffices to categorize the bird as such and immediately we know that it breathes, that it reproduces through hard-shelled eggs, that it flies and has a habit of banging its beak against trees in order to obtain its daily dose of small insects hiding in the bark. We do not have to observe these features, nor are we consciously aware of them. Essentialism makes it possible to generate a plethora of inferences simply on the basis of category membership. These inferences are there for the taking and available when we need them. Similarly, our intuitive psychology functions as an inference system. A 1944 classic video by Fritz Heider and Marianne Simmel features three geometric objects, two triangles and a circle, moving across the screen. Our understanding of objects is usually guided by our intuitive physics, which includes the expectation that objects do not move unless a force (by another object or an agent) is exerted unto it. The simple fact that these objects move by themselves triggers our intuitive psychology, which immediately starts to make inferences about what these objects are up to. As a result, the mind makes up a story that runs more or less as follows: two lovers, one of the triangles and the circle, are being bullied by the other triangle. In the end, the two lovers leave and the bully in anger rips the place apart (a rectangle suggesting the presence of a room). It is remarkable how little information, how little input we need to conjure up such a scenario. We do not see the love of the two objects or the anger of the bully, nor can they tell us how they feel. We simply infer their emotional states from the objects moving in particular ways. And we are able to do so because our intuitions provide us with a rich understanding of how people behave under particular circumstances. Again, the example of natural selection demonstrates how these inference systems can be recruited in scientific thinking. By coining the term "natural selection," Darwin could not only rely on the inferences that became available through the analogy with artificial selection. It is also an intentional term that elicits intuitive inferences about agents that Darwin could employ to reason about natural selection.

Analogies are of course not the only means to scaffold cognition and to put intuitions to work in scientific reasoning. In fact, scientific reasoning only becomes possible through the availability of a cognitive environment that includes both ecological and psychological scaffolds that lift up our intuitions and cognitive abilities. Professional scientists are trained to acquire a specific terminology, use and manipulate particular objects, and conduct a series of practices that are typical of their field. They have learned to memorize relevant facts about the subject they are studying, think differently about certain entities (e.g., species as a population of slightly varying individuals instead of an essence) and they keep their knowledge up-to-date by consulting the relevant literature. Moreover, they rely on colleagues whom they expect to have gone through a somewhat similar training and who will be interested in more or less the same issues and share the same epistemic background. These practices and social relations are embedded within institutional arrangements (procedures, peer-reviewed journals, organizations). The resulting shared cognitive environment prevents scientists from holding naive assumptions about the world and helps them to produce and maintain highly counterintuitive scientific concepts and theories. Without this environment, science would simply not be possible.

Educating and Communicating Science

Imagine what would happen if you introduced scientific concepts in an environment that is different from the one shared in scientific communities, an environment that lacks the scaffolds that enable scientists to push the barriers of our knowledge. What would happen to these concepts? In fact, this is not difficult to imagine at all, because it happens all the time. Through science education, communication, and popularization, scientific concepts are transmitted from the environment in which they have been developed, maintained, and become ingrained in brains that lack the necessary background and motivation to process them properly. What happens all too often is that these brains then transform these concepts into types that are easier to work with, in other words, into intuitively more appealing types. As a result, people misrepresent scientific information in systematic ways, leading to detectable patterns. For instance, surveys show that students do not distort basic concepts of evolutionary theory in any odd way, but hold misconceptions that betray essentialist, teleological, and intentional biases. Another example is that people typically expect a ball that leaves a curved tube to continue moving in a curve, instead of proceeding in a straight line as predicted by modern physics (McCloskey et al., "Curvilinear Motion"). And so on. In a cognitive environment without sufficient support, our intuitions easily play up as biases again.

The fact that scientific concepts require proper scaffolding and the right environment to flourish poses formidable challenges to science educators and communicators who transmit and explain these concepts under less suitable conditions. It does not suffice to simply communicate scientific ideas, because students and lay people will not understand them and quickly transform them into more palatable, but scientifically inaccurate versions. Thus, educators need to develop and employ practices and tools that enable people to apprehend the science correctly. One approach is to partly reconstruct some of the scientists' environment in the classroom. For instance, teachers can challenge students to develop hypotheses, test them against the facts, and discuss their results with classmates. Such experiences might induce them to revise their earlier, intuitive beliefs with scientific beliefs that are more capable of explaining what they observed. Another approach makes use of thinking aids. Analogies and metaphors are excellent examples of such aids, but they are not the only ones. Drawings and models, for instance, help us to visualize a scientific concept, which in turn assists us to understand the issue at hand. Scientists use them to clarify their thinking—Darwin's coral drawing in his 1837 notebook comes to mind—but teachers can apply them equally well in the classroom. For instance, Kelemen and her colleagues showed that picture storybooks can be used to teach the basics of natural selection to 5- to 8-year-olds (Kelemen et al., "Young Children"). Note how these educational solutions do not exclusively depend on students' reflective reasoning. Surely, they involve some reflection, as learners have to make a sustained and conscious effort to overcome their intuitive theories and to understand and accept scientific beliefs. To a large extent, however, these tools also rely upon intuitions and mental capabilities shared by all students (e.g., testing hypotheses, visualizing objects and scenarios, finding reasons). As scientific thinking depends upon intuitions, it would be truly surprising if science education did not.

The classroom setting is special in the sense—and to the extent—that it allows for the re-creation of certain aspects of scientific practices, for systematic and sustained ways of teaching, and for the continuous control and correction of misconceptions. In other words, teachers can partly reconstruct the necessary cognitive environment in which scientific concepts hold sway. Nonetheless, it is remarkable how, even under these relatively favorable circumstances, students experience great difficulties coming to terms with scientific beliefs. In the case of the public understanding of science, science communicators do not have the same opportunities to manage and control how people receive and understand the message they want to convey. When one reaches out to a lay audience, either directly or via the media, it is difficult to have the public engaged in experiments or to systematically check and correct for misunderstandings. All one can do is communicate in the hope that one will instil at least a minimal public understanding of the scientific content. However, the odds are very much against communicators, as distortions may occur at several levels. Many people are simply not interested in scientific issues, so even if the communicated message reaches them, they will at most assimilate only a fragment of the information. In the case that people do pay attention, they might have motivations other than a concern for truth that constrain the way in which they perceive and interpret scientific information. Religious, political, and ideological beliefs can seriously affect people's understanding and acceptance of scientific concepts and theories. Creationists will treat any confirming piece of information about evolution with great scepticism, argue against it, or transform it into a belief that fits within their religious framework. Such views are enforced by alternative sources of information that people consider to be authoritative but that contradict the science. Environmentalist groups, for instance, oppose genetic modification in agriculture and thereby use intuitively appealing but inaccurate representations of GMOs. Finally, even if people are genuinely interested in learning about scientific matters, they usually do not have the time and energy to acquire a full understanding and also lack the right background knowledge and institutional support to interpret the information correctly. On other occasions, people will claim to accept a scientific belief without properly understanding its content (Guillo, this volume).

Intuitions have an effect at each of these levels. Generally, people feel no need to acquire a scientific understanding, as scientific matters are often too complex to understand and are usually redundant in people's daily lives. They prefer the messages that align most closely with their intuitive understanding of the world and the ideas that are popular within their own cultural environment, giving trust to the sources that provide such information and distrusting others. Finally, intuitions bias people towards reconstructing highly counterintuitive scientific content in the direction of more cognitively palatable notions. However, intuitions not only affect the transmission of scientific ideas at the receiver's end, but also at the end of the sender. In order to make scientific concepts and theories more salient and more understandable, science popularizers lower complexity and make their message more intuitively appealing. Think, for instance, of the interactions between several different species within a particular environment. A scientific evolutionarily informed look at these ecological patters discloses a ruthless struggle for survival under harsh conditions and an endless competition for resources between individuals, not the least within the same species. Death and spoilages are distressingly common, and preying and parasitism are the most common form of interorganismic interactions, while not uncommon instances of symbiosis or cooperation are merely driven, or at the very least facilitated, by genetic "interests." Environmental factors such as predators, disease, and lack of food sources keep each species in check, thereby creating an equilibrium that gives the impression of a delicate balance. However, this balance can easily be disturbed. If an individual organism or species has the opportunity, it will exploit its environment to the fullest and flourish to the detriment of others. Maintaining the "balance of nature" would be the least of its concerns. Nevertheless, documentaries tend to present the delicate relations between and within species in a narrative of a harmonious and almost romantic play, written by nature, in which each species knows and plays it role. Such a presentation may help to convey the correct idea that species depend on one another for survival (e.g., as a food source, shelter). Moreover, it may help to raise public concern about the annihilation of valuable ecosystems. It also, however, romanticizes nature and thus misinforms people about how ecosystems function. Romantic views tap into our essentialist, teleological, and intentional biases: individual organisms are regarded as representatives of their species and can easily be replaced. Tens and tens of individual blackbirds may die, but as long as one blackbird sings in the dead of night, we behold the beauty of nature. The delicate balance between organisms is not regarded as emerging from interactions between individuals but as the very goal of such interactions, either intended by the individuals themselves, evolution, or Mother Nature. Such views, however, fail to address and emphasize the important Darwinian point that ecosystems consist of countless individual interactions in which not the conservation of the system but the survival and the reproduction of organisms, or, in ultimate (genecentric) terms, protection and spreading of genes is at stake.

Such examples make clear that it is not just the case that people distort the scientific content that they receive, but that the content itself is already distorted before it reaches them. Egil Asprem discerns two steps in which science becomes transformed through popularization, driving theories towards cognitively optimal forms ("How Schrödinger's Cat"). In the first step, the theory is translated into common language that consequently taps into our intuitions. Asprem discusses the example of genetic determinism (a gene for this, a gene for that) that thrives on our preferences for monocausal explanations. In a second step, causal explanations are warped in the cloak of intentionality by means of analogy, thus exploiting our folk psychology. As we have seen, Darwin's use of natural selection in *On the Origin of Species* stands out as an example, but Asprem himself refers to the popular concept of the selfish gene, coined by the British biologist Richard Dawkins. Dawkins has always emphasized that it was just a metaphor to facilitate the understanding of genecentrism and should not be taken literally—although he has made this mistake himself. "Nevertheless," as Asprem notes, "Dawkins opened a can of worms. The metaphor invites readers to process the science in ways that are antithetical to its theoretical content" ("How Schrödinger's Cat" 121). As Darwin had done more than hundred years before, Dawkins, unintentionally, confuses his audience by using intentional language as a communicational tool.

Conclusion

In science intuitions play a double part. As biases they tend to distract scientists from finding out how the real world functions, and they have induced scientists to develop practices, tools, and methods to counter their influence. As scaffolds, intuitions play a pivotal role in the construction of counterintuitive ideas, and hence they are essential to the progress of science. However, this is only possible given the right cognitive environment in which both psychological and ecological factors enable the development of scientific concepts. This double role of intuitions puts science educators and communicators in a precarious position. On the one hand, they need to find ways to override them if they want to succeed in instigating a conceptual change in their learners or members of the audience. On the other hand, they have to employ the very same intuitions as stepping-stones towards a scientific understanding. One way to walk this delicate line is to translate the complexity of scientific theories into more intuitively appealing notions, but the examples of natural selection and the selfish gene clearly indicate that this strategy is risky. Another option might be to use less enticing machine metaphors (Tanghe, "Robots"; but see Pigliucci and Boudry, "Why Machine-Information").

So how should teachers proceed? What educational tools and strategies can they deploy to develop a scientific understanding of the world in their students or audience but avoid the pitfalls of intuitive reasoning? Limitations of space prevent us from going into the practical details, but we will conclude with some general remarks. First, teaching science definitely requires a good understanding of the human mind. Teachers and communicators should be aware that students or lay people do not receive scientific information like a tabula rasa's inscriptions, but instead they will have intuitive expectations of how the world functions. These expectations, in combination with people's acquired beliefs, concerns, and motivations, lead people to transform scientific information in ways that they find relevant. And this is certainly not always in the direction of accuracy. Second, knowledge about the human mind should result in the design and application of educational tools, methods, and strategies that are targeted at overcoming such systematic biases and misconceptions. Teachers and communicators should not simply transmit scientific content, but think very hard about how they can accomplish this. Already there is plenty of literature available in which one can find helpful suggestions. Third, good educational tools foster a scientific understanding of the world by building on people's intuitive reasoning. Teachers and popularizers should not be afraid of using metaphor, analogy, images, models, and narratives to help their learners understand scientific theories. As we have seen, these same tools help scientists to develop their theories. However, one should always be careful that these tools do not enforce people's intuitive reasoning (see also Shtulman, this volume). And finally, ideally these tools and strategies take part in the development of a cognitive environment that raises the relevance of representing scientific beliefs correctly. This is easier said than done, especially in the context of the public understanding of science, but it is absolutely necessary if we want to live in a scientifically informed culture. Given the risks and dangers entailed in rampant irrational beliefs and practices, that goal is certainly something worth aiming for.

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Chapter 13

Vindicating Science—By Bringing It Down

Maarten Boudry and Massimo Pigliucci

Abstract

Science, in the classical view, is the epitome of a rational endeavor, untrammeled by social and cultural influences. It strives to reflect the way the world really is, and is elevated above our petty human lives. Social explanations come into view only when science goes astray—when it stops being science. In recent decades, radical sociologists and other science bashers have tried to wrestle away science from the upholders of the classical view, bringing it down to the level of other human endeavors. Science, they maintain, is social to the bone, and what passes for scientific knowledge is nothing but a fabric of social constructions and power relations. In turn, this radicalism has fueled suspicions among science advocates about any naturalized conception of science: the edifice of science should be free from the contamination of social influences. Both parties in the dispute, as we argue in this chapter, buy into an intuitive view that characterizes much of our everyday reasoning about the causes of belief: a stark opposition between the rational and the social. Wherever social influences hold sway, reason takes the hindmost. And wherever reason reigns, no need is felt for social explanations. This opposition harks back to an even more basic intuition: true and justified beliefs don't require a causal explanation. They are just self-evident. We grapple for causal explanations (social or otherwise) only when rationality fails. This assumption, handy though it is as a heuristic and first approximation, does not survive careful scrutiny, and needs to be abandoned. A rich causal account of

> science, including the constitutive role of the social, in no way detracts from its epistemic credentials. Science, after all, is the concerted effort of many human brains. If we want a nonmiraculous explanation of science's successes, we had better be able to account for them in social terms.

What is the role of the social in science? If one consults science textbooks, one will find that the social dimension of scientific knowledge is conspicuously absent. Science is supposed to reflect the way the world really is, independent of our petty human lives. It is, in the classical view, the epitome of a rational endeavor, free from social influences. Of course, science is carried out by human beings, but their individual backgrounds and social lives are simply taken to be irrelevant. Individual scientists are effaced from the fruits of their intellectual labors, or relegated to historical footnotes. What matters are the intellectual merits of a theory, not who conceived it. What matters is the evidence, not who gathered it. This stark contrast between the social and the rational can be found in philosophical accounts of science as well. Because social factors are rendered invisible in the end products of science, many philosophers have underestimated their constructive role in the acquisition of scientific knowledge.

In recent decades, sociologists and historians have tried to bring science back to earth, but many of them have unwittingly bought into the same simplistic opposition. Social influences on science have been relished by its cynical critics and resisted by its admirers, and for the same reason: the fear (or hope) that it would destroy the credentials of science. In what follows, we discuss the historical roots of this opposition, culminating in the sorry spectacle of the science wars. We also point to a deeper cognitive explanation for this battle over the social nature of science: our basic intuition that rationally justified beliefs are not in need of any explanation, and that only false and foolish ones are.

Explaining Rational Belief

When do we feel the need to explain why someone believes something? Not all beliefs held by our fellow human beings appear to produce an epistemic itch. People believe that dolphins are mammals, that the earth orbits the sun, and that World War II ended in 1945, but we rarely wonder how they arrived at such homely truths. Beliefs such as these are just obvious, and no sane person would dispute them. Not only are we not interested in how other people came to hold these beliefs, we are also oblivious to how we did so ourselves. Who told you when the World War II ended? Where did you acquire the belief that dolphins are mammals, or that the earth goes around the sun? Your sources for these convictions, though you surely must have had them, are hard to track down.

Psychologists distinguish between episodic memories and semantic memories (Squire and Zola, "Episodic Memory"). Episodic memories carry a mental source tag, containing the time, place, and situation where we acquired them. Semantic memories, by contrast, are floating unanchored in our mental space: we can no longer retrieve the moment in our lives when we first learned that dolphins are mammals, although surely there must have been such a moment. Knowledge about biological taxonomy is not innate, and in fact, as in the case of dolphins, it is often surprising and counterintuitive.

There are good reasons why our brains don't bother to keep a source tag for semantic memories: doing so would just clog our memory, and be a waste of brain resources. Take the belief that coal is black. People may have acquired this knowledge in any number of ways: some may have learned about soil deposits and compression of organic matter in elementary school, others had first-hand experience with the substance as a child, before learning about its origins. Still others may have learned about coal from the accounts of parents or friends. None of this is consequential for the end result: the culturally shared knowledge of a black, solid, combustible material called "coal."

If we ask you what your reasons are for believing that coal is black, you would probably be puzzled. The first answer that comes to mind is: "Why, because it *is* black, of course!" It doesn't matter how I came to know that. I could have learned it in any number of ways. Anyone in doubt about the color of coal can quickly retrieve the answer through any number of sources.

Because the truth of such beliefs is obvious, we rarely question how other people acquired them, or how they can justify them. It seems as if such beliefs just drop out of thin air, without much in the way of a causal history. People have many beliefs about the world, or so we think, simply by virtue of these beliefs corresponding to the way the world really is. If we are pressed to come up with a causal history of such beliefs, we say that people must have been exposed, one way or another, to the right kind of evidence or testimony. If such evidence is available in abundance, there is no need to worry about the details. In traditional accounts of knowledge, the explanation for true belief is pretty straightforward, as Paul Boghossian writes: "Under the appropriate circumstances, our exposure to the evidence alone is capable of explaining why we believe what we believe" (22).

Explaining other Beliefs

So how do we account for other kinds of beliefs (as held by others, of course)? Beliefs that are false, quirky, idiosyncratic, or plainly irrational produce an epistemic itch. We want to explain how people end up embracing them. Confronted with someone who believes that coal is red, that ostriches are mammals, that cellphones cause cancer, or that Elvis is still alive, we grapple for explanations. Who told him such nonsense? Is he the victim of some sort of prank? Did he fall for one of those conspiracy theories circulating on the Internet? Some beliefs are so blatantly false that we begin to question someone's sanity, or we assume that there must have been some sort of misunderstanding (Davidson).

In terms of accounting for why people believe certain things, we resort to special explanations only when something goes wrong. True beliefs that are part of common knowledge are taken at face value, but false and foolish beliefs cry out for an explanation. Some distorting influence is needed to explain why someone has arrived at a belief that no rational person would hold. This is where social and cultural explanations come in. We refer to someone's upbringing or social milieu, his allegiances and prejudices, and we invoke concepts such as peer pressure, indoctrination, misinformation, or ideological posturing. We say that someone is being contrarian, gullible, prejudiced, or trying to save face.

Such explanations, however, are not invoked when we account for true and justified beliefs, especially the countless mundane beliefs that all of us share. Only when rationality breaks down, it seems, a space is opened up for psychosocial explanations to fill. This association between the irrational (or arational) and the social works also in the opposite direction: if X comes up with an explanation of Y's belief in terms of social factors, we assume that X is dismissing Y's belief, or at least not taking it at face value. In folk psychology, rationality is the default of belief formation (Dennett; Bortolotti), but reasoning can be contaminated by social and psychosocial factors. Wherever the social holds sway, we should be suspicious.

This assumption that true beliefs don't need a causal pedigree, unlike false ones, has even dominated much of academic psychology. For a long time psychologists have investigated deviations from the canons of rationality (Kahneman et al.), documenting all the biases and errors that human reason is liable to, but they have been much less interested in the cognitive mechanisms of rational belief updating (Krueger and Funder). True beliefs, it seems, take care of themselves.

Explaining Science

In the classical view, science is (supposed to be) the epitome of reason. It is objective and impartial. It is ruthless in its indifference to what we fear or fancy. When it comes to the content of science, nature has the final say in the matter. Social, political, and ideological influences on science are anathema. If they have any discernible effect on science, then something must have gone wrong, and we are no longer talking about science. As the physicist Steven Weinberg put it: "Whatever cultural influences went into the discovery of Maxwell's Equations and other laws of nature have been refined away, like slag from ore" (qtd. in Hacking 86). Indeed, the contamination by the social is one of the diagnostic criteria to distinguish science from pseudoscience. In many pseudoscientific theories, we see that ideological fashions and cultural sensibilities, rather than evidence, are the prime movers of theory development (Boudry and Buekens; Pigliucci and Boudry).

When writing science textbooks, and for many other purposes, the social influences on the development of scientific theories can be safely ignored, just like with many of our mundane beliefs about the world. Sure, there is a story to be told about how scientists pooled their efforts to acquire this or that piece of knowledge, who published it first, who convinced whom, and so on. At some point, so we assume, scientists must have been exposed to the relevant evidence. But the details of this story make no difference: an alternative history of science would ultimately have led to the same result. Not surprisingly, many textbooks of science have markedly little interest in the history of the laws and theories being discussed, or even in their evidential support. Scientific theories are timeless and universal, transcending the particular historical context in which they emerged. Especially in the natural sciences, students are simply taught scientific theories as if they descended down from some Platonic heaven. The vagaries of scientific history, the false starts, wrong turns, and dead ends, the protracted controversies between rival views, the forerunners and pioneers of scientific ideas—all of this is rendered invisible.

There are of course eminently good reasons for this neglect in scientific textbooks. Once a scientific theory has been firmly established, and its last reputable dissenters have died out or given up, the history of its eventual rise and triumph becomes a matter for historians and sociologists. There is no need for students of physics to linger over the priority dispute between Newton and Leibniz about the invention of calculus, or the chronological development of special and general relativity, at least not when it comes to understanding these theories and putting them into practice.

For long, philosophers of science have also treated science in splendid isolation from the social world. Philosophy of science, under the influence of logical positivism, and in particular Gottlob Frege's attack on psychologism (Friedman), was mainly concerned with the logical structure of scientific theories, the relationship between theoretical propositions and observations, and the procedure or method for accumulating scientific knowledge. The philosopher Hans Reichenbach, one of the major proponents of logical positivism, taught us to strictly separate the *context of discovery* from the *context of justification*. The first deals with the historical conception of a scientific hypothesis, or the circumstances in which some observation has first been made, and is of little interest to philosophers trying to understand the logic of science. Brilliant ideas and findings may be arrived at in any number of ways, by anyone, under whatever circumstances. No rhyme or reason to be found there.

Philosophers of science, according to Reichenbach's famous stricture, should be solely concerned with how a scientific hypothesis, once it appears on the scene, relates to observations, whether it is internally consistent, whether it is falsifiable, and so on. The latter issue, which Reichenbach called the context of justification, deals exclusively with the logical relation between scientific hypotheses and the world, and is unaffected by the context of discovery (Schickore). There is no need to belabor the shortcomings of this highly idealized conception of science, as those have been amply exposed elsewhere (Creath). Perhaps more important is to see that, despite the obvious problems with this exclusive focus on the logic of justification, there is a sensible rationale behind the distinction. The ultimate goal of science is indeed to cancel out any influence of the social and to retroactively erase its own history: scientific theories have to stand or fall on their own merits, independent from their originators.

Down to Earth

In this idealized conception of science, which focuses on the successful end result of scientific activity, there is no place for any influence of the social, or indeed, for any of the actors involved in the scientific endeavor. All of that is swept under the carpet. But the fact that the eventual goal of science is to eliminate the social does not imply that social factors have no important role to play in the process. Science, after all, is nothing but the concerted effort of (sometimes not so) humble human brains, none of which was designed to unravel the mysteries of the world on its own.

In the past couple of decades, science has been brought down to earth again by sociologists, cognitive scientists, evolutionary psychologists, and historians. Unfortunately, the opposition between the rational and the social is still besetting the naturalization of science. The backlash against the traditional conception of science, epitomized by the logical positivists and their intellectual heirs, has swung the pendulum in the opposite direction. Still under the spell of the dichotomy between rational and social (Galison), many science naturalizers have assumed that, as they bring science down to earth, its pretensions will start to unravel.

In *The Structure of Scientific Revolutions,* Thomas Kuhn famously argued that the history of science can be divided into periods of normal science, punctuated by episodes of revolution. During times of normal science, all scientists work within a certain paradigm, sharing background knowledge, methodologies, experimental procedures, and rules of inference. Nobody questions the validity of the reigning paradigm. The period of normal science ends when a critical level of "anomalies" has accumulated, that is, empirical and conceptual problems that the ruling paradigm has trouble dealing with. This crisis eventually leads to a revolution and a paradigm shift, after which normal science resumes again.

In periods of normal science, uncritical acceptance of the reigning paradigm is ensured through social conformity and transferred from the old generation to the new. During the revolutionary period, in Kuhn's picture, the social dynamics of science are even more important. This is because the old and the new paradigm, according to Kuhn, are "incommensurable," meaning that the choice of one paradigm over the other cannot be settled by rational means. It is akin to a gestalt switch, where two different conceptual frameworks offer a completely different perspective on a given phenomenon.

Many philosophers of science dismissed Kuhn's notion of paradigm shifts and incommensurability as a form of "mob psychology." In describing this gestalt switch between the old and the new, however, Kuhn opened up a space for social influences on science, which some sociologists have enthusiastically exploited and, to Kuhn's own dismay, pushed beyond what he himself thought reasonable. In the end, "whether a revolution occurs or the anomalies are simply ignored," as Golinski summarized, the approach of the radical sociologists "would depend on the social configuration of the community" (25). Sociologists such as Harry Collins came to the rather surprising conclusion (to most scientists at any rate) that "the natural world has a small or non-existent role in the construction of scientific knowledge" (3).

There is a continuing debate about the legacy of Kuhn's work, and the correct interpretation of such ambiguous terms as "incommensurability" and "paradigm." In any case, as sociologists were following up on (what they claimed to be) Kuhn's lead, philosophers of science tried to reinstate the distinction between the rational and the social, carving out a restricted niche for social explanations. The proper place for the social was mainly defined in a negative fashion. Imre Lakatos, who was attempting to incorporate Kuhn's insights into the falsificationist philosophy of his mentor Karl Popper, used the notion of "research program" as a unit of analysis of the history of science, a less encompassing concept than Kuhn's "paradigms." According to Lakatos, good science proceeds in a rational way, unless or until a scientific research program starts to degenerate. When science shows signs of such degeneration, we can no longer explain what happens in a purely rational fashion, and we must look for additional social and psychological accounts. In other words: when rationality breaks down, the sociologists are allowed to jump in the fray. Larry Laudan, another important philosopher influenced by Kuhn, explicitly defended what he called the "arationality assumption": "The sociology of knowledge may step in to explain beliefs if and only if those beliefs cannot be explained in terms of their rational merits" (202).

Both the strictures of Lakatos and Laudan, as well as the sociological relativism that they were battling against (Koertge), rest on the false opposition which we outlined above: when it comes to understanding why people believe certain things, we only look for psychological and social explanations when something goes wrong. From a pragmatic point of view, in other words, the social becomes salient only when rationality fails us. The truth of the matter, however, is that all beliefs, the true and the false ones alike, have a causal history, involving cognitive and social factors (in varying combinations). If we want to understand how people come to believe stuff, even simple and obvious propositions (e.g., dolphins are mammals) are in need of an explanation. Likewise, if we want to understand how scientists have been able to unearth all sorts of true beliefs about the world, we need to understand what kinds of people scientists are, what kind of cognitive strategies they bring to bear on their research questions, what the social organization of science is, and how hypotheses are tested and evaluated within a scientific community (Longino, *Science as Social Knowledge*; *The Social Dimensions of Scientific Knowledge*).

Opposing the Rational and the Social

The development of a cognitively and socially rich account of science has been delayed by the widespread misconception that such an account would compromise the epistemic standing of science (Haack). Because of our habit of pitting social and rational explanations against each other, we assume that the intrusion of sociology and psychology into the citadel of science will eat away at its foundations. As Philip Kitcher writes: "Much thinking about the growth of science is permeated by the thought that once scientists are shown to be motivated by various types of social concerns, something epistemically dreadful has been established" (305).

Or, as the radical sociologists would have it, something exquisite: this would finally bring down science as one worldview among many, with its own power structures, social dominance relations, and coalitions (Bloor). If we succeed in encroaching on the domain of science, so the sociologists seemed to think, surely we are debunking its epistemic pretensions. Why else were the traditional guardians of science trying to keep us out? Despite its lofty epistemic ambitions, science is shown to be nothing more than a social construction, and can be treated accordingly, in just the same way that sociologists treat religion and politics. At the heart of this opposition between the social and the rational, according to Mercier and Heintz, lies an individualist conception of reason, shared by both camps in the science wars: "On the science war front, both camps see reason as the ultimate place that is safe from sociological analysis. Defenders of the rationality of science against relativism could put rationality just there: in scientists' reasoning capacities. Protagonists on the other side of the front have seen in reasoning another attempt to resist naturalistic inquiries" (Mercier and Heintz 515). Mercier and Heintz are defending a deeply social account of human reason, according to which its prime function, from an evolutionary point of view, is to argue with other people. This, not coincidentally, is also the ecological setting in which human reason is most successful. Mercier and Heintz's view goes against the traditional concept of reason, in which others are seen as potential confounders or distorters, and human reason is regarded as a cognitive faculty that works best in isolation, free from external influences.

This idea of the social as a contaminant of the rational, to which even social constructivists seem to subscribe, is more indebted to logical positivism than the latter would like to admit. Radical sociologists were led astray by the very same intuition that made the logical positivists allergic to social explanations—only now they were welcoming the opposite conclusion. David Hull expressed their line of reasoning as follows: "Because science did not possess the ideal characteristics that the 'positivists' insisted that it should, knowledge-claims made by scientists had no more warrant than those of magicians, faith healers, and politicians" (Hull xi).

It is not surprising that such iconoclasm has further entrenched the conviction that sociologists should get their dirty hands off the edifice of science. If the content of scientific theories were determined by social factors, by ideological fashions, or by the psychological quirks of scientists, how do we explain the impressive technological prowess of science? Science is a way of finding out objective truths about the universe. We don't need sociologists to explain the triumph of the germ theory of disease. Microscopic organisms really make us ill, social constructivism be damned.

Naturalizing Science

In our view, both camps are wrong (although, arguably, the relativist science bashers more so). The simple opposition between the rational and the social-psychological explanations goes against the grain of naturalism. Scientific knowledge does not drop out of thin air: it is embodied in real human beings. If our best scientific theories in some way reflect the world out there, this must have come about through the usual perceptual capacities and cognitive operations, with available technological equipment, and in a complex network of social interactions. How else could it have come about?

Science itself, after all, tells us that the human brain is a product of evolution by natural selection, and science the product of cultural evolution (Heintz, this volume). Humans did not evolve to unravel the structure of the cosmos. Indeed, evolution has equipped us with a host of biases and intuitions that served our ancestors well in the environment in which they had to survive and reproduce, but that often get in the way of our modern quest to uncover the nature of the universe (Blancke, Tanghe, and Braeckman, this volume). If humans succeed in overcoming these intuitions regardless, developing scientific theories that violate their intuitive worldview at every turn, then we need some nonmiraculous, bottom-up, naturalistic account of this achievement. The sociologists are right that science is a deeply social endeavor, and that all scientific knowledge is in this sense "socially constructed." No single individual marooned on a desert island, no matter how brilliant, would be capable of finding out any of the significant truths about the universe that we currently possess. Though the history of science has known some solitary geniuses, working in relative isolation from their peers, even they were still engaged in a collective enterprise, in the sense that they were building on the work of numerous predecessors. Isaac Newton was standing on the shoulders of giants (and it's giants and lesser giants all the way down). If we want to understand anything at all about the accomplishments of science, we need to solicit the help of sociologists.

The realization that science is a deeply social enterprise, and that scientific consensus is reached through coalition forming and competition, should not surprise us. The question is what particular social organization is exemplified by science, and whether this is conducive to its epistemic aspirations. Scientists are human beings, warts and all. If scientists collectively succeed in finding out significant truths about the universe, while other endeavors have failed in this regard, this must have come about through the particular social dynamics of science.

Luckily, this research is now well underway. The discipline of social epistemology is investigating the particular social arrangements that are successful in producing knowledge (Goldman). Philip Kitcher, in his seminal *The Advancement of Science,* has developed a model of the microstructure of scientific change, paying attention to the division of cognitive labor and the social organization of science. Ronald Giere has investigated the phenomenon of "distributed cognition" in science ("Scientific Cognition as Distributed Cognition"). Hugo Mercier and Christophe Heintz have described scientific reasoning as inherently social and argumentative ("Scientists' Argumentative Reasoning"). To dissolve the opposition between the rational and the social, let us briefly consider some social influences on science, which, though initially seeming to threaten its epistemic ambitions, are actually enlisted in the interest of scientific progress.

Positive Roles for the Social

Many scientists believe that being objective and impartial are the cardinal virtues of science, and that bias and prejudice make one unsuitable for scientific work. Although the culture of science rightly encourages these virtues, they are by no means necessary for the success of science. Indeed, a certain modicum of bias in this or that direction may actually facilitate the progress of science.

It is not a problem that an individual scientist is biased, or emotionally attached to a particular hypothesis. The social organization of science makes sure that these biases will be balanced by others tilting in different directions. Helen Longino, for example, has put forth an account of the importance of epistemic diversity in the workings of science, arguing that (near) objectivity in scientific endeavors emerges from two sources: on the one hand, science constantly confronts itself with the reality of the world, as assessed by our best empirical methods (*Science as Social Knowledge*). This leaves comparatively little room for (reasonable) alternative views: it is a matter of fact whether light is bent by gravitational fields, as the general theory of relativity predicts. On the other hand, the more cultural, gender, and ideological diversity there is within the scientific community itself, the more likely it is that culture-, gender-, or ideology-specific biases will be corrected. A standard example of this is the reorientation of aspects of medical research as a result of feminist epistemological critiques: it is now increasingly acknowledged that, for example, we cannot conduct drug tests solely on a population of (mostly white, middle aged) men and simply assume that the results can be extrapolated to other human biological populations (Gesensway).

In general terms, a good social arrangement for finding out the truth of some matter is to have two or more competing groups pursue different hypotheses, trying their utmost to garner evidence for their own view and to prove competitors wrong. As David Hull writes, with regard to the ideal of objectivity in science: "The objectivity that matters so much in science is not primarily a characteristic of individual scientists but of scientific communities. Scientists rarely refute their own pet hypotheses, especially after they have appeared in print, but that is all right. Their fellow scientists will be happy to expose these hypotheses to severe testing" (3–4). In other words, it is best to let a thousand flowers bloom in science. Even if you think some hypothesis is unlikely and far-fetched, it might still be worthwhile for some scientist to pursue it. The reward structure of science ensures that even implausible hypotheses will be explored by someone: there is a high premium on being able to show that a certain orthodox or received view is wrong. The chances of succeeding are dim, but then again, the reward is huge. This social arrangement attenuates the risk that science, as a whole, misses out on an apparently unlikely alternative that might be borne out after all.

Many controversies in science can be viewed as a battle between the opposing biases of conservatism and rebelliousness. According to Philip Kitcher, cognitive variation among scientists on this dimension is conducive to progress in the long run (*The Advancement of Science*). Some scientists are mavericks, quick to challenge established views and pursue new avenues, while others are traditionalists, suspicious of radical ideas and inclined to defend the orthodoxy as long as possible. There is no single strategy that is always successful: the mavericks take more risks and will often turn out to be wrong, but may sometimes strike gold and thus prevent the ossification of scientific orthodoxy. Traditionalists are often right in sticking with the old ways, and are not the ones to waste time and effort on wild and improbable ideas. But sometimes they will be proven wrong too. There is no single ideal way to strike a balance between caution and innovation, between persistence and flexibility. A social arrangement that allows for different cognitive strategies to flourish, according to Kitcher, will produce better results than one that attempts to enforce one single "rational" policy.

A desire for fame and success is often viewed as unworthy of a real scientist. The goal of science is truth for its own sake. Although such base motives may indeed compromise one's scientific work, if allowed to be unchecked, there is no convincing reason why they would stand in the way of significant discoveries. Even spite, jealousy, and the desire to humiliate a rival can result in excellent scientific work, if the competing parties know that they have to abide by certain rules, and will be called out whenever they violate them. In any case, a desire for fame and success does not compromise the collective goals of truth and objectivity. Institutional arrangements provide selfish motives for honesty and truthfulness in reporting and sharing results with others (Campbell; Goldman; Haack).

Indeed, social competition may be more effective as an incentive to do science than the pure and noble goal of discovery, especially when it comes to the laborious and repetitious work that science often demands. As Susan Haack puts it, competition is "an aid to our limited energy and fragile intellectual integrity" (108). Scooping a rival may be more thrilling than laying another brick in the edifice of knowledge, but that's no problem, as both may be accomplished at the same time. Fraud is ruthlessly punished in the world of science, not just because it undermines the relationship of trust on which science is based, but also because it is an unfair shortcut to the success and professional achievement that many scientists are striving for. What goes for individual rivalry also applies to competition between research groups, as David Hull writes: "As unseemly as factionalism in science may be, it does serve a positive function. It enlists baser human motives for higher causes" (349).

In all these cases, social influences are not an impediment to the epistemic ambition of science, but rather a facilitator of scientific progress. Science harnesses some of the baser motives of human behavior in the service of truth, making sure that the interplay of scientists' individual interests and biases mostly align with epistemic progress. Social constructivists are right that, in the battle between competing paradigms (or research programs), the social configuration of the research community plays an important role. This is especially true in the early stages of scientific research, when evidence is still ambiguous and incomplete, conceptual problems abound, and social factors are given free rein. Even the final vindication of the correct scientific theory, however, is also accomplished through social means: forming alliances, maintaining a good reputation, showing courage to challenge received views, and exercising restraint in attacking rivals.

Charles Darwin may have been right from the start about the fact of common ancestry, but his theory would not have carried the day as swiftly as it did without Darwin's indefatigable efforts to enlist allies to the cause and to engage and negotiate with his critics. All the parties in the dispute were trying to enlist nature as their ally, but Darwin of course had one big advantage: nature really was on his side all along. In the long run, therefore, as evidence accumulates and factions wax and wane, the social influences on science will be filtered out, and rightly so.

Conclusion

The development of a thoroughly naturalistic account of science has been delayed by the widespread misconception that this would compromise its epistemic standing. Sociological accounts of science have been met with distrust by lovers of science, and have been relished by its cynical critics, giving them ammunition to undermine science's lofty pretensions. Beneath the surface, these apparently rival views are committed to the same assumption: that social intrusions into science would undermine its epistemic ambitions. The only difference is that one party welcomed this prospect, while the other loathed it.

But the assumption is false. Science is social to the bone. No single human brain would be capable of accomplishing any of science's successes in isolation from others. Science is nothing but the concerted effort of fallible human brains to understand nature. As science itself tells us, those biological organs evolved for other activities than unraveling the structure of the cosmos. Science contains many safeguards against the contamination of social factors (e.g., double blind procedures), but in many respects, the social structure of science, along with the social relations between its actors, are conducive to its successes. Even the baser motives of the human mind—pride, jealousy, revenge—can be enlisted for the benefit of science.

It is true that the eventual goal of science, as a collective human endeavor, is to efface human actors and their social lives from view. If we ever find out that the theoretical content of our best scientific theories reflects the ideology of its originators rather that an approximate understanding of the world as it is, or if it carried the day for purely sociological reasons, then something would be seriously wrong. That would be a reason to start all over again. Science, then, is the sustained social effort to create something from which, eventually, the social will be eradicated.

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Part 4

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Thematic Bibliography of Publications on Different Perspectives on Science and Culture

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